DREDGED MATERIAL RESEARCH PROGRAM

MISCELLANEOUS PAPER D-77-3

FEASIBILITY OF PINTO ISLAND AS A LONG-TERM DREDGED MATERIAL DISPOSAL SITE

by

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December 1977

Final Report

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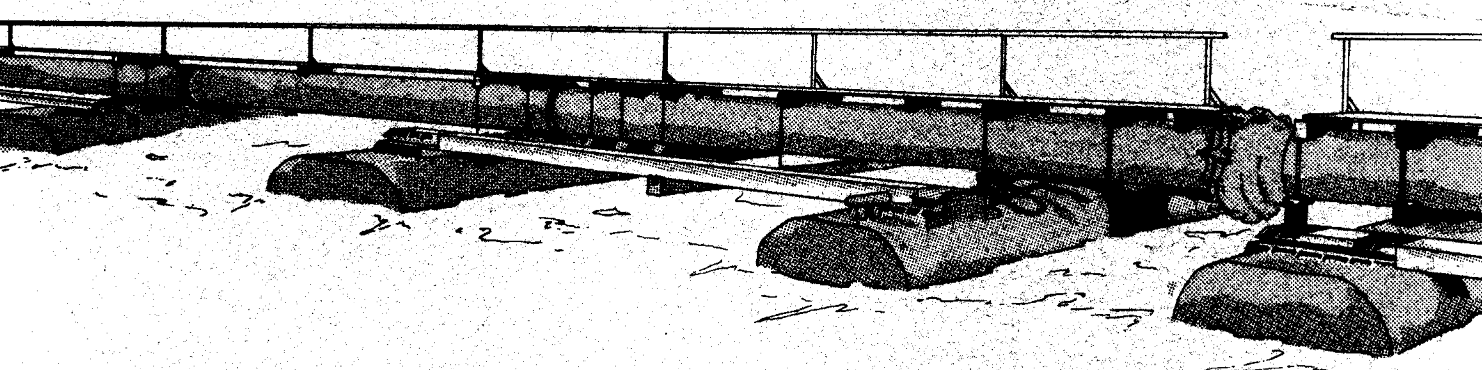

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Under DMRP Work Unit No. 5A16

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21 December 1977

SUBJECT: Transmittal of Miscellaneous Paper D-77-3

TO: All Report Recipients

1. The report transmitted herewith represents the results of a study conducted as part of Task 5A (Dredged Material Densification) of the Corps of Engineers' Dredged Material Research Program (DMRP). This task is part of the Disposal Operations Project of the DMRP and is concerned with developing and/or testing promising techniques for dewatering or densifying dredged material using physical, biological, and/or chemical techniques prior to, during, and/or after placement in the containment area. Although the work was conducted as part of Task 5A, many concepts being developed as part of Task 2C (Containment Area Operations) were directly applicable to the work. In Task 2C, new or improved methods for operation and management of confined disposal areas and related facilities are being developed.

2. The rapidly escalating requirements for land for the confinement of dredged material, often in urbanized areas where land values are high, dictated that significant priority be given within the DMRP to research aimed at extending the useful life of existing or proposed containment areas. Life expectancy of the areas can be extended through proper design and management, and dewatering concepts can be an integral part of site management. In fact, dewatering concepts may be the only practical way of achieving extended site life of the type authorized by Section 148 of Public Law 94-587. Proper management of the sites and densification of the material will not only increase the site capacity but also will result in an area more attractive for various subsequent uses because of improved engineering properties of the material.

3. This study was a cooperative effort by the U. S. Army Engineer District, Mobile (MDO) and the Waterways Experiment Station (WES) to illustrate application of technology developed by the DMRP in the solution of actual field problems. The study sought to determine if a site on Pinto Island near Mobile, Alabama, could be used as a long-term disposal facility to contain maintenance dredged material from the Mobile River. Survey data, foundation characterization, and background data were provided by MDO while evaluation and assessment were conducted by WES. Using DMRP-developed concepts, plans were designed for optimum use of the site including details of sequential construction, dredged material dewatering, and productive use of dewatered dredged material.

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4. Two alternate disposal area configurations to provide adequate capacity through the year 2007 or the year 2019 are proposed. Total costs of disposal area construction, operation, and maintenance are estimated for each alternative. Data are presented in sufficient detail to allow MDO and local-sponsor decisions concerning potential feasibility of Pinto Island as a future long-term disposal site.

5. It is believed that the concepts presented herein provide a sound basis for the planning and management of the Pinto Island disposal area. Although the concepts are applied specifically to Pinto Island, the methods are applicable in the general sense. It is anticipated that the methods will be modified with time as current concepts are improved and new concepts are developed.

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Miscellaneous Paper D-77-3	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): FEASIBILITY OF PINTO ISLAND AS A LONG-TERM DREDGED MATERIAL DISPOSAL SITE	5. TYPE OF REPORT & PERIOD COVERED: Final report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): T. Allan Haliburton, Environmental Effects Laboratory, Jack Fowler, Soils and Pavements Laboratory, Patrick A. Douglas, U. S. Army Engineer District, Mobile	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U. S. Army Engineer Waterways Experiment Station, Environmental Effects Laboratory, P. O. Box 631, Vicksburg, Miss. 39180 and U. S. Army Engineer District, Mobile, Mobile, Ala. 36628	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: DMRP Work Unit No. 5A16
	12. REPORT DATE: December 1977
11. CONTROLLING OFFICE NAME AND ADDRESS: Office, Chief of Engineers, U. S. Army, Washington, D. C. 20314	13. NUMBER OF PAGES: 53
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dredged areas
Dredged material disposal
Feasibility studies
Pinto Island
Waste disposal sites

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study was a cooperative effort by the U. S. Army Engineer District, Mobile (MDO) and the U. S. Army Engineer Waterways Experiment Station (WES) to illustrate application of technology developed by the Dredged Material Research Program (DMRP), administered by WES, in solution of field element problems.

The study sought to determine if a site on Pinto Island, near Mobile, Alabama, could be used as a long-term disposal facility to contain maintenance

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DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued).

dredging material from the Mobile River. Survey data, foundation characterization, and background data were provided by MDO, while evaluation and assessment were conducted by WES. Using DMRP-developed concepts, plans were developed for optimum use of the site, including details of sequential construction, dredged material dewatering, and productive use of dewatered dredged material.

Two alternate disposal area configurations to provide adequate capacity through the year 2007 and through the year 2019 are proposed for consideration by MDO. For each alternative, total costs of disposal area construction, operation, and maintenance are estimated to be approximately $0.40 per cubic yard of storage capacity. Data are presented in sufficient detail to allow MDO and local sponsor decisions concerning potential feasibility of Pinto Island as a future long-term disposal site.

Appendix A presents a preliminary design for the Pinto Pass dikes.

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PREFACE

This report presents the results of a study conducted under the Dredged Material Research Program (DMRP), Disposal Operations Project (DOP), Task 5A, "Dredged Material Densification," Work Unit 5A16, "Feasibility of Pinto Island as a Long-Term Dredged Material Disposal Site," the purpose of which was a practical application of DMRP-developed technology to overall confined disposal area design, operation, and management. The DMRP is sponsored by the Office, Chief of Engineers (DAEN-CWO-M) and is administered by the Environmental Effects Laboratory (EEL), U. S. Army Engineer Waterways Experiment Station (WES). This study was conducted by EEL in cooperation with the U. S. Army Engineer District, Mobile (MDO).

Survey, foundation characterization, and background data were provided by MDO under the general direction of Mr. Patrick A. Douglas, Civil Engineer, Foundations and Materials Branch, MDO. Evaluation and assessment of the data and proposed site operational procedures were developed by Dr. T. Allan Haliburton, DMRP Geotechnical Engineering Consultant, EEL. Mr. Jack Fowler of the WES Soils and Pavement Laboratory assisted Dr. Haliburton in the preparation of the preliminary design for Pinto Pass dikes. The report was prepared under the general supervision of Mr. Harvey N. Blakeney, Chief, Foundations and Materials Branch, MDO; Mr. Frank Deming, Chief, Engineering Division, MDO; Mr. Charles C. Calhoun, Jr., DOP Manager, EEL; Dr. Roger T. Saucier, Special Assistant for Dredged Material Research, EEL; and Dr. John Harrison, Chief, EEL. Overall guidance in the conduct of the study was provided by Mr. J. Patrick Langan, Assistant Chief, Project Operations Branch, Operations Division, MDO. This report was written by Dr. Haliburton and Mr. Douglas. Mr. Fowler assisted Dr. Haliburton in the preparation of Appendix A.

District Engineers of MDO during the conduct of the study and preparation of this report were BG Drake Wilson, CE, and COL Charlie L. Blalock, CE. Directors of WES were COL G. H. Hilt, CE, and COL John L. Cannon, CE. The WES Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	2.54	centimetres
feet	0.3048	metres
square yards	0.8361274	square metres
acres	0.40468	hectares
cubic yards	0.7645549	cubic metres
pounds (mass)	0.4535924	kilograms
pounds (force) per square foot	47.88026	pascals
pounds (force) per lineal foot	14.5939	newtons per metre

FEASIBILITY OF PINTO ISLAND AS A LONG-TERM DREDGED MATERIAL DISPOSAL SITE

PART I: INTRODUCTION

Background

1. In recent years, increasing national environmental concern has resulted in restriction of open-water and unconfined land disposal of dredged material, as well as restriction of the use of wetlands for confined disposal site construction. However, cessation of dredging, especially in maintenance of existing navigable waterways of the United States, would have disastrous effects on the Nation's commerce and economy. To assist in resolution of these potentially conflicting national needs, the Dredged Material Research Program (DMRP) of the U. S. Army Corps of Engineers was initiated to study the dredging and disposal process to develop environmentally compatible, technically feasible, and cost-effective methods for dredging and dredged material disposal, including reclamation and use of dredged material as a resource. This program is administered by the Environmental Effects Laboratory, U. S. Army Engineer Waterways Experiment Station (WES).

2. In recent years, the Operations Division of the U. S. Army Engineer District, Mobile (MDO), has become vitally concerned about obtaining adequate long-term confined disposal capacity in Mobile Harbor, especially to provide for continuing maintenance dredging activities in the Upper and Lower Tangents of the Mobile River from the Bankhead and Lurleen Wallace (I-10) Tunnels upriver to above Cochrane Bridge. Most of the material dredged from these reaches has been placed in the North and South Blakeley Island Disposal Areas (Figure 1), with some deposition on Pinto Island. However, the Blakeley Island sites are fast approaching the end of their useful life.

3. The South Blakeley Island site will, for all practical purposes, be filled when MDO dredges the Lower Mobile River in 1977. Existing

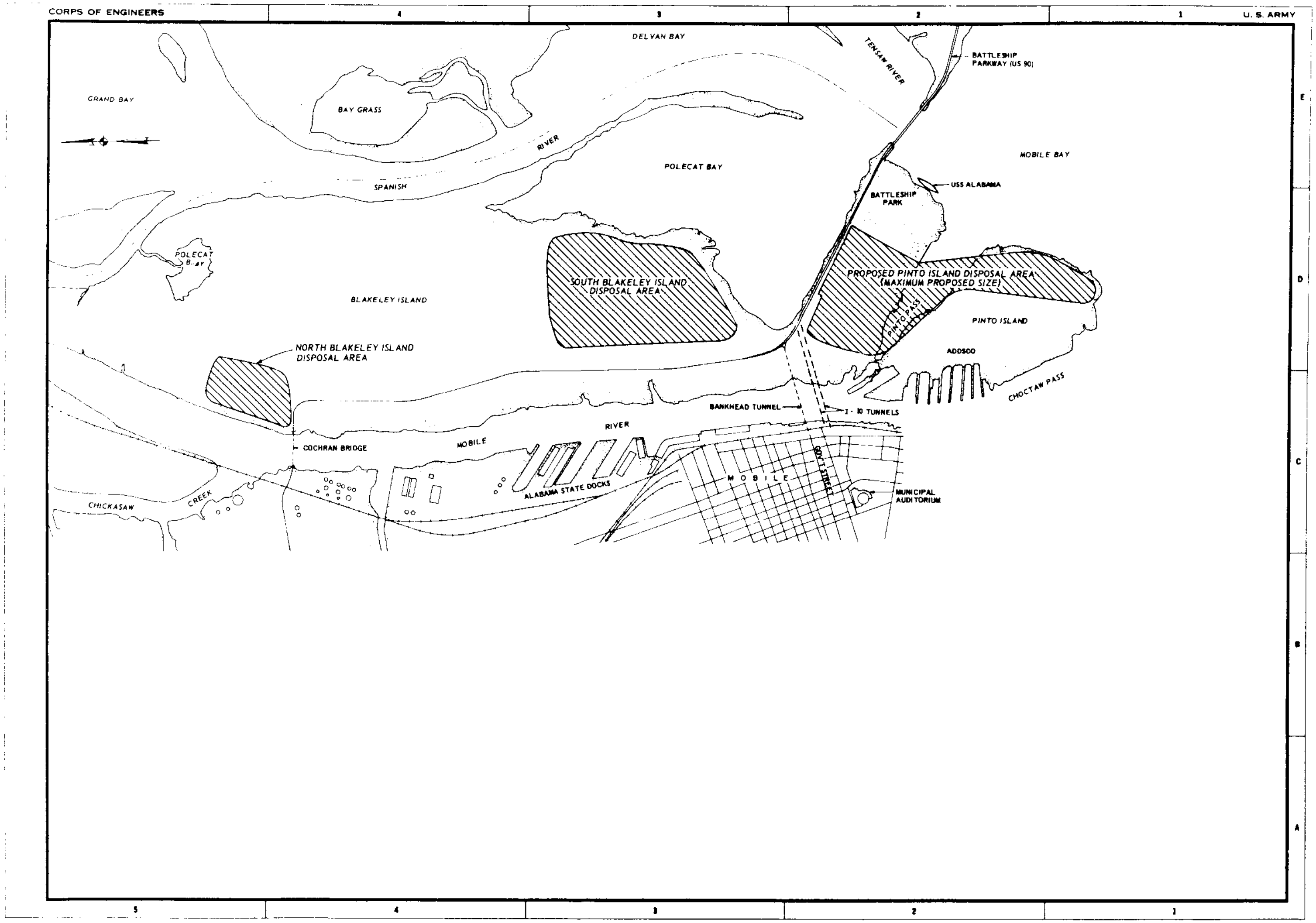

Figure 1. Mobile Harbor and vicinity showing North and South Blakeley Island Disposal Areas and proposed Pinto Island Disposal Area

perimeter dikes at this site have reached their maximum technically feasible height without extensive and expensive renovation. It is planned to raise the dikes at the North Blakeley Island site in 1977 sufficient to double its existing storage capacity to 2.4 million cu yd.* However, it is estimated that this capacity will be exhausted by the early 1980's. Unfortunately, because existing MDO agreements with the local sponsor at these sites are of an extremely short-term nature, expenditure of funds does not appear justified for implementation of long-term site operation and maintenance programs needed to increase storage capacity radically.

Purpose and Scope

4. The long-term plan and environmental impact statement for dredging in Mobile Harbor indicated that if technical feasibility could be established and long-term land-use agreements made with the local sponsor, a MDO disposal site could be established on Pinto Island at the general location shown in Figure 1. Therefore, as part of a multifaceted cooperative effort between the MDO Operations Division and WES, this study was conducted to apply DMRP-developed technology and long-range planning concepts to the critical MDO disposal problems. The study was designed to determine if, through use of DMRP-developed concepts and planning, adequate long-term capacity could be developed at Pinto Island for disposal of MDO maintenance dredging from the Upper and Lower Tangents of the Mobile River.

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is found on page 4.

PART II: PLAN DEVELOPMENT

Existing Site Conditions

5. Pinto Island, shown in Figure 1, has had a long history of use as a dredged material disposal area. The southern part of the proposed disposal site, bounded on the south and east by Mobile Bay, on the north by Pinto Pass, and on the west by a railroad and the Alabama Dry Dock and Shipbuilding Company (ADDSCO), has been diked and filled to about el 10 to 15* by past disposal operations, primarily with sand from new-work dredging.

6. The northern part of the proposed site, actually the southern tip of Blakeley Island, is bounded on the east by fill placed to construct a motel, on the north by rights-of-way and improvements along U. S. Highway 90, on the south by Pinto Pass, and on the west by the access road leading to ADDSCO. Previous diking and dredged material disposal in this area have resulted in filling to el 2 to 6 over much of the site.

7. Pinto Pass forms the center portion of the proposed site. This outlet was considerably deeper in the past as seen from survey data indicating a maximum water depth of 9 ft in 1852. However, continued shoaling and erosion of adjacent filled areas have gradually filled the pass, so that the maximum water depth is about 2 ft at high tide and most of the area is exposed as a mud flat at low tide. This center section is bounded by Mobile Bay to the east, existing low dikes along the south tip of Blakeley Island to the north, a bridge and the ADDSCO access road to the west, and existing dikes and a parking lot and railroad to the south.

Assumptions Used in Planning

Maintenance dredging volume

8. Estimated volumes of future maintenance dredging for the Upper

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* All elevations (el) cited herein are in feet referred to mean sea level.

and Lower Tangents of the Mobile River were based on MDO dredging data available for the 10-year period 1966-76. Data indicated average sediment dredging volumes of approximately 1.4 million cu yd with 30-month frequency for the Upper Tangent and 0.9 million cu yd with 24-month frequency for the Lower Tangent. Dredging volumes included measured overdredging. The frequency base was determined by assuming that both Upper and Lower Tangents would be dredged during 1977.

9. The most critical assumptions made were that dredging would continue for the next 40 years at volumes and frequencies measured over the last 10 years and 1 cu yd of channel sediment would be contained in 1 cu yd of disposal area storage volume. While the estimated dredging volumes in the former assumption were computed from best available data, it must be noted that such volumes are invalid if any conditions upriver cause a change in the rate of shoaling or if future modifications to existing navigation channels cause a change in the volume and/or frequency of anticipated dredging. Further, the estimated quantities have no provision for any new-work volume that might be required in modification of existing channels, or for any dredging disposal from state or local government or private sources. The effect of the latter assumption (1:1 sediment-dredged material volume) will be discussed later.

Available disposal volume

10. Available volume of the proposed Pinto Island Disposal Area was computed for two site configurations (to be described subsequently). The following assumptions were made in developing relationships for available disposal volume with time. The effects of these assumptions will be discussed later.

a. Dredged material will be placed in the disposal site hydraulically in slurry form and will consist primarily of fine-grained material from maintenance dredging activities.

b. One cubic yard of disposal area storage volume will contain 1 cubic yard of channel sediment in decanted dredged material form.

c. The disposal site will be subdivided into three compartments: north, center, and south. The north compartment has north frontage on U. S. 90; the center compartment is composed primarily of Pinto Pass; and the south compartment abuts on ADDSCO property.

d. Environmental and land-use constraints and foundation conditions will allow ultimate dike construction to el 50, but volumes were also computed for lower dike elevations.

e. The site will contain permanently emplaced piping and valving such that disposal flow may be routed to any of the three compartments as desired during any given disposal operation to allow placement of dredged material in lifts of 3 ft or less of sedimented thickness.

f. The center compartment will contain approximately 6000 lin ft of piping and a manifold system to facilitate deposition of coarse-grained dredged material adjacent to and along the center compartment perimeter dike.

g. Fine-grained material placed in the area from maintenance dredging may be reduced by approximately 25 percent of its initial sedimented volume in one year by maintaining good surface drainage with a Riverine Utility Craft (RUC) or similar vehicle.

h. All material used to construct and raise site perimeter and interior dikes will be obtained onsite.

i. All initial dike construction will be completed by the end of 1979.

j. It is technically feasible to initially construct dikes to el 8 along and across Pinto Pass.

Effect of assumptions

11. The assumptions made in developing data presented herein increase the uncertainty of estimated disposal area useful life. The uncertainty of assumptions related to construction and operational procedures may be negated by simply incorporating them as chosen methods in the final plan for Pinto Island. Other assumptions about material quantities and costs could be refined by developing an operational plan that would allow continuous update as better data become available. Two key assumptions were made:

a. The estimates of annual and cumulative volumes of dredging and available disposal area were developed assuming a 1:1 correspondence between volume of sediment dredged and volume of decanted dredged material placed in the disposal area. While appropriate for preliminary estimates, this relationship could be but probably is not true, and it is equally probable that the error in the assumption is on the unsafe side. Thus, translation of feasibility concepts into detailed designs and site operation and maintenance procedures at some future date will require use of sediment sampling and testing techniques and volumetric prediction methodology developed by the DMRP to refine predictions of the volumetric storage needed to contain the estimated volume of maintenance dredged material.

b. Dredging volumes were estimated from past data and do not reflect any possible future changes in maintenance dredging requirements. Further, and perhaps more importantly, estimated useful life data were computed based on volumes that did not include disposal from non-Corps sources. The error in this assumption may well be on the unsafe side.

Effective Disposal Area Life

12. Based on assumptions described in the preceding paragraphs, required dredging volume with time and availabe disposal volume were computed using two disposal site configurations (Plans C and A shown in Figure 2). Plan C encompasses a total disposal site size of 243.0 acres; and Plan A adds another 145.1 acres, most of it in the north section, for a total area of 388.1 acres. A third configuration, Plan B, was used during preliminary planning, but was discarded as it gave results similar to those of Plan C. The two site configurations were chosen, after consultation with the MDO Operations Division, as the two most efficient and logical configurations from a construction and operation standpoint. DMRP-developed criteria for disposal site shape and configuration based on aesthetics and maximum habitat development were not applied, as the general site configuration had been previously established by negotiations between MDO and state and local agencies. A compartmentalized design was chosen for ease of operation, especially in meeting probable effluent standards. However, other configurations are possible so long as the three-compartment concept is retained.

13. Annual and cumulative estimated dredging and available disposal volumes for Plans C and A for 1977 through 2020 are tabulated in Table 1 and are plotted in Figure 3. As noted in Table 1 and Figure 3, for dike construction to el 50, the disposal site configuration of Plan C would be filled to capacity in 2007, having had a useful life of approximately 30 years. If the disposal site configuration of Plan A is used, available capacity would be exceeded in approximately 2019,

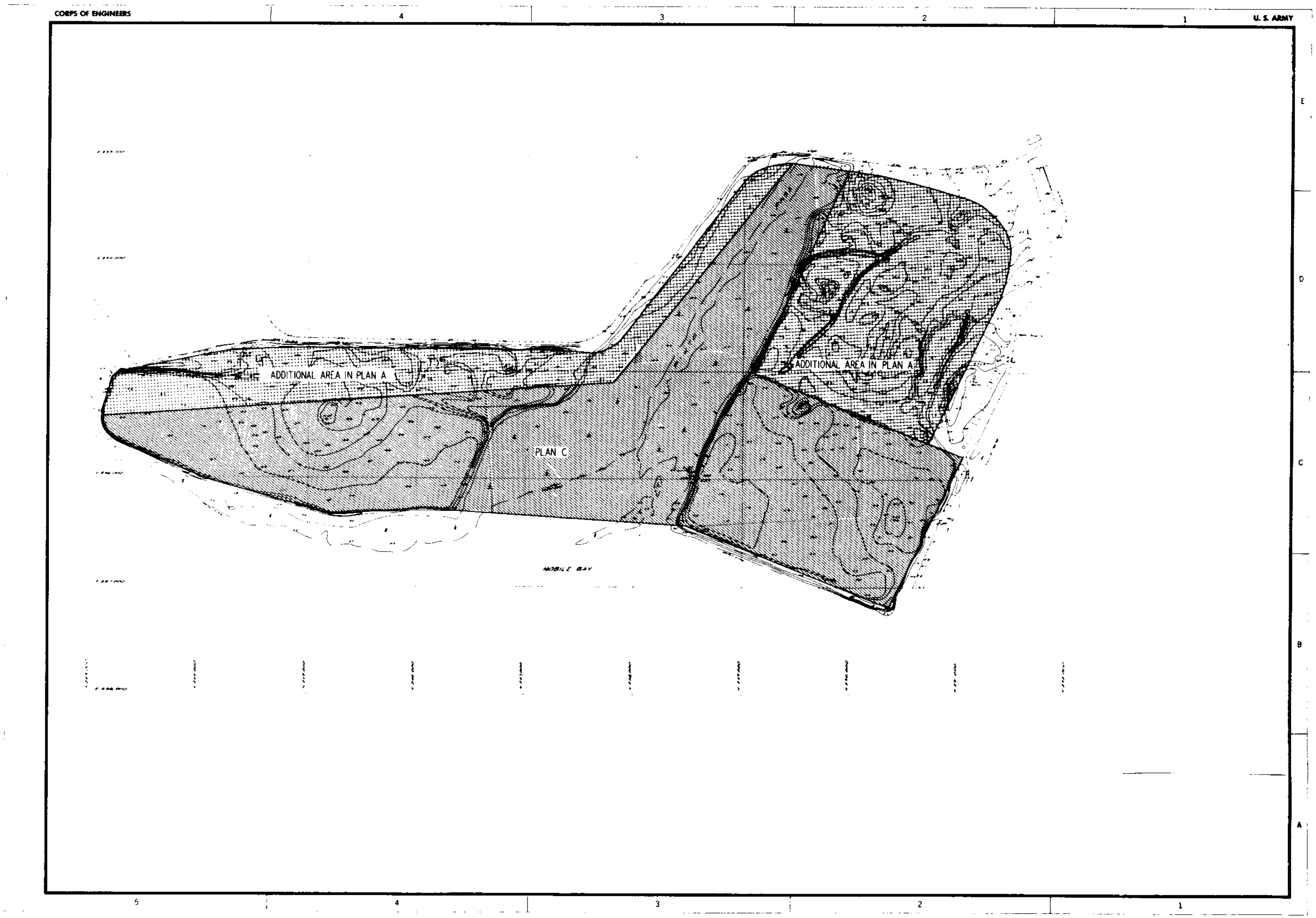


Figure 2. Disposal site configurations for Plans C and A

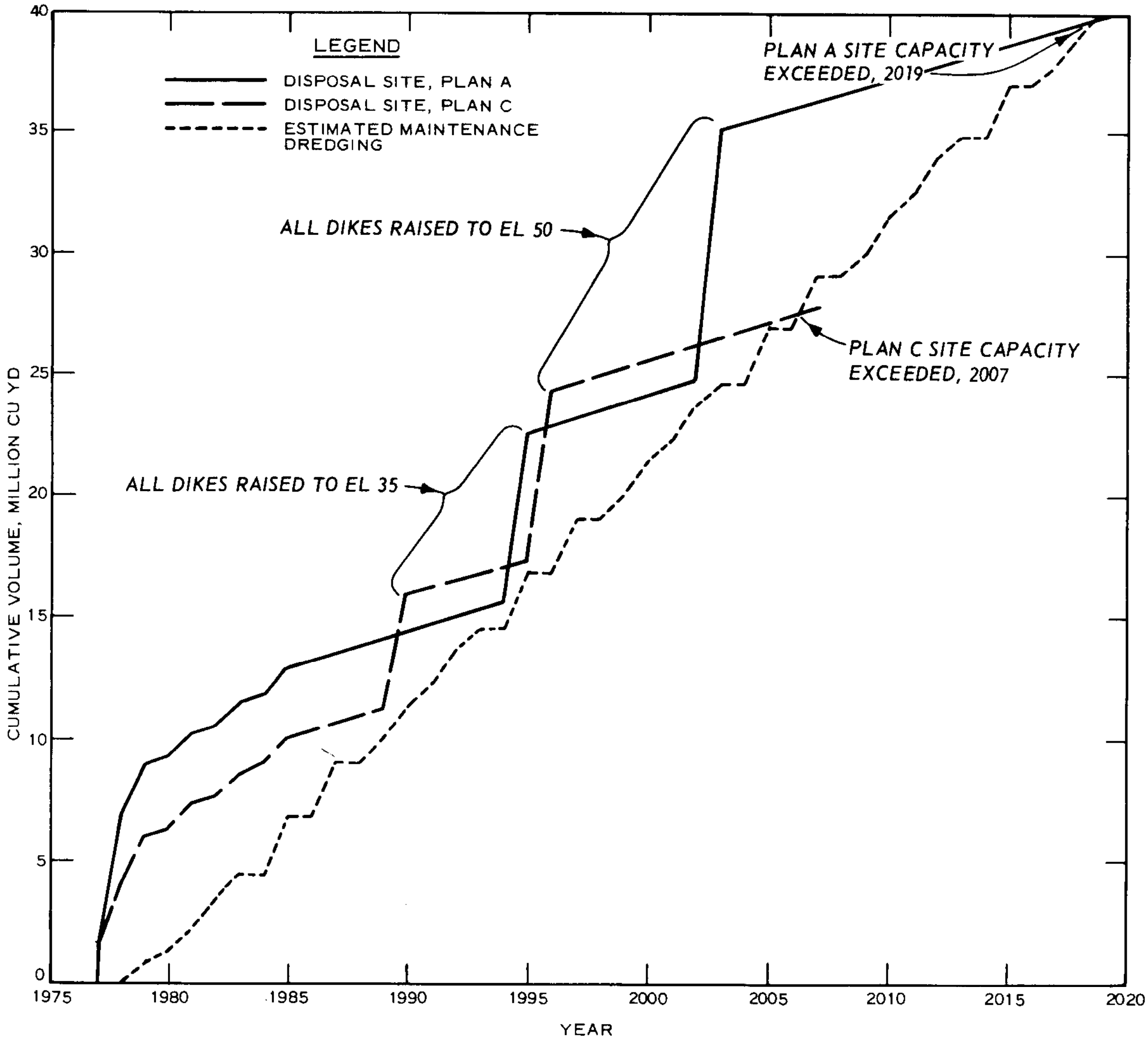


Figure 3. Estimated dredging volume and available disposal area volume with time for the proposed Pinto Island Disposal Area

giving a useful life of approximately 42 years. If dikes are raised only to el 35, site capacity would be exceeded in 1996 for Plan C, giving a useful life of 19 years, while for Plan A, site capacity would be exceeded in 2003, giving a useful life of 26 years. If dikes are raised only to el 25, Plan C capacity would be exceeded in 1989, a 12-year useful life, while Plan A capacity would be exceeded in 1994, a 17-year useful life. The large increase in useful life obtained by high dike construction is evident from these data.

Assumed Sequence of Construction Operations

Disposal site configuration A

14. Preliminary foundation exploration and characterization studies by the MDO Foundations and Materials Branch (F&MB) indicated that a good supply of coarse-grained material, deposited from previous disposal of material from new-work dredging, is available for initial dike construction in the north and south compartments of the proposed disposal site. However, once this material is covered by fine-grained maintenance dredging material, it will no longer be readily accessible. Thus, initial dike construction activities must be scheduled and coordinated for maximize use of available onsite high-quality borrow material prior to disposal.

15. The required sequence of construction operations is described as follows and is shown in Figure 4.

- a. 1977. A low multipurpose (containment and preload) dike will be constructed to el 8 across both ends of Pinto Pass and along the south shore of the pass, connecting with existing dikes that are at or above el 8. Borrow for this dike construction will be removed from the south compartment of the disposal site.
- b. 1978. Perimeter dikes around the north compartment of the disposal area will be raised to el 25 using coarse-grained borrow from the north compartment.
- c. 1979. The perimeter dike around the south compartment of the disposal area will be raised to el 25, and the low dikes across and along the south edge of Pinto Pass will be raised an additional 4 ft to el 12. Coarse-grained

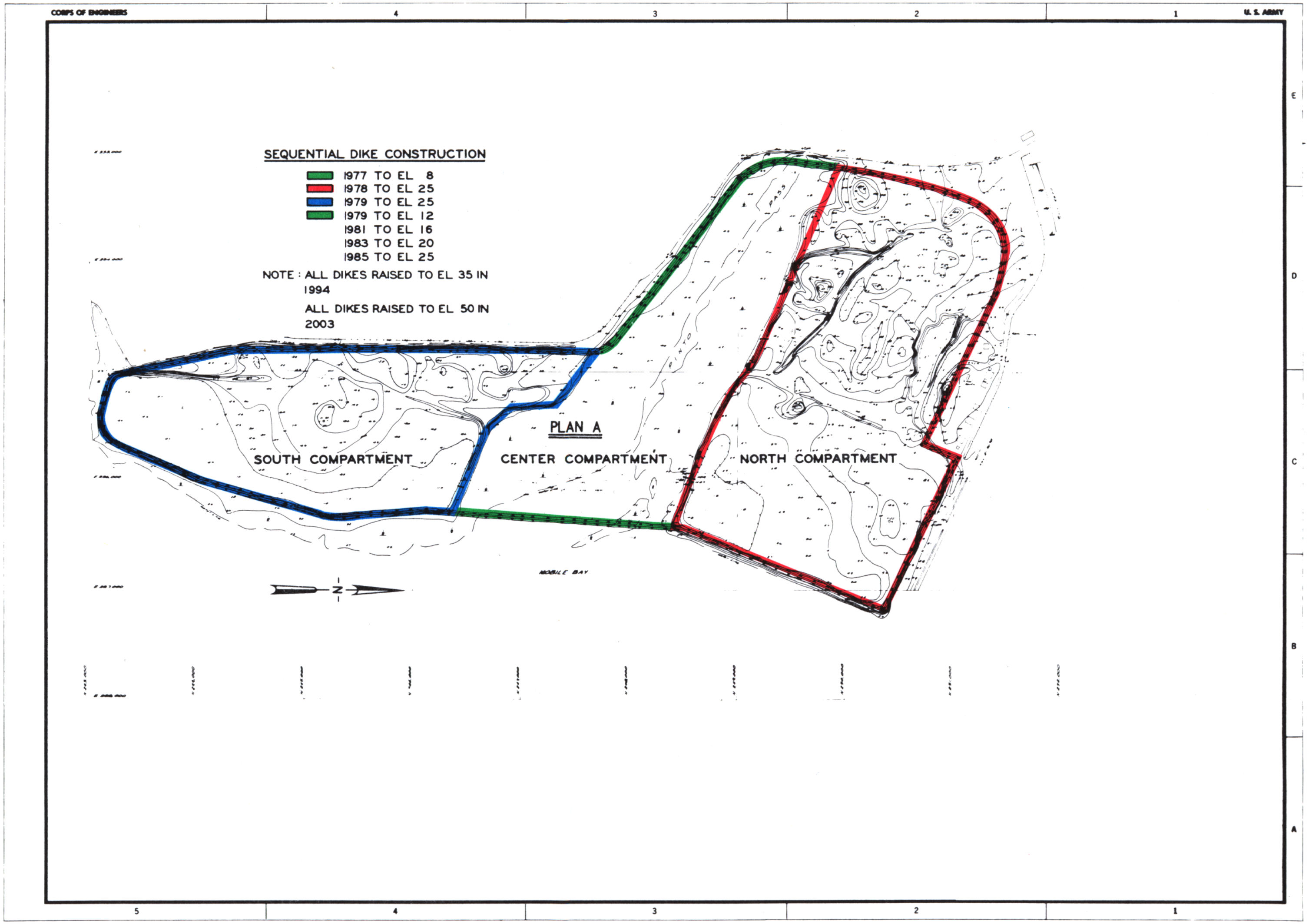


Figure 4. Sequence of construction operations for Plan A site configuration

borrow material for use in this dike construction will be removed from the south compartment of the disposal area.

d. 1981. The dike across each end and along the south edge of Pinto Pass will be raised an additional 4 ft to el 16 using a combination of coarse- and dewatered fine-grained dredged material as described in subparagraph c above.

e. 1983. The dike across each end and along the south edge of Pinto Pass will be raised an additional 4 ft to el 20, using a combination of coarse- and dewatered fine-grained dredged material as described in subparagraph c above.

f. 1985. The dike across both ends and along the south edge of Pinto Pass will be raised an additional 5 ft to el 25, matching other dike elevations, again by use of a combination of coarse-grained and dewatered fine-grained dredged material as described in subparagraph c above.

g. 1994. All existing perimeter dikes will be raised an additional 10 ft to el 35 using a combination of coarse-grained and dewatered fine-grained dredged material available in the disposal area.

h. 2003. All existing dikes will be raised an additional 15 ft to el 50 utilizing a combination of coarse-grained and dewatered fine-grained dredged material from inside the disposal area.

Disposal site configuration C

16. The proposed construction operations and time sequence for Plan C are similar to those described for Plan A, except that the dike along the south edge of Pinto Pass is constructed farther out into the pass along the approximate tidal line and the sequence of dike raising calls for all perimeter dikes to be raised to el 35 in 1989 and to el 50 in 1995. Construction operations sequence is shown in Figure 5.

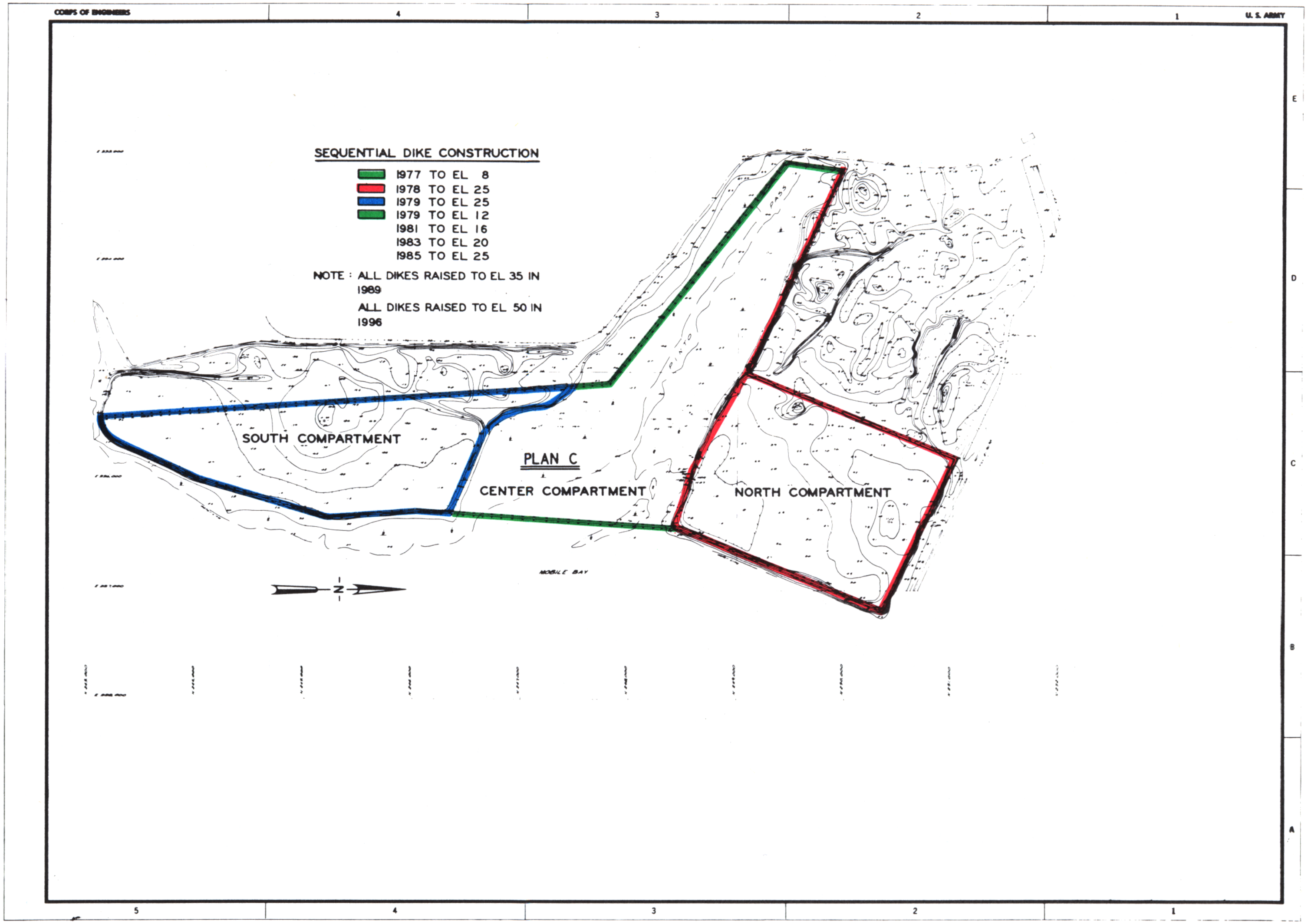


Figure 5. Sequence of construction operations for Plan C site configuration

PART III: PLAN IMPLEMENTATION

Description of Foundation

17. A general foundation exploration for characterization purposes was carried out over the majority of the site by F&MB. Historical survey data on accretion in Pinto Pass were provided by both the Site Development Branch, Engineering Division, and the Mobile Area Office, Operations Division, MDO. Foundation exploration and sampling were carried out across both ends and along the south edge of Pinto Pass by the WES Mobility and Environmental Systems Laboratory. Except for the sampling in the Pinto Pass area, all of the exploration was of a general nature to obtain information needed for determination of initial conceptual plans and site feasibility.

18. A general characterization of the area indicated that above approximately el 0, site soil conditions were somewhat varied, as might be expected from past history as a dredged material disposal site. The majority of material appeared to be from previous new-work dredging and consisted of medium to very fine sands and silty sands with intermixed silt and clay lenses and pockets. Relative density of the coarser grained material varied from medium to very loose, with relative density decreasing at lower elevations.

19. From el 0 down to approximately el -10 to -20, soils consisted either of medium to very fine sands and silty sands with intermixed silt and clay stringers or of highly plastic soft to very soft organic clays, silty clay, and silts. The fine-grained materials were probably deposited by shoaling and accretion, while the coarse-grained materials deposited during previous dredged material disposal operations have either displaced or consolidated the fine-grained sediments. Below approximate el -20, the primary soil type encountered over much of the site consisted of soft to very soft highly plastic organic and inorganic silts and clays underlain by medium dense to very dense medium sand at el -30 to -50.

20. The major exception to this general soil profile occurred

across both ends and along the south tidal edge of Pinto Pass. There, for all practical purposes, material of extremely low strength (primarily very loose sand and highly plastic organic clay) existed from the surface, about el -2 to +2, down to the medium dense to very dense sand at approximately el -40.

21. An assessment of potential foundation problems likely to occur during life of the disposal site indicates that the problems may be subdivided into those dealing with long-term settlement and those relating to stability of dikes, during both construction and site operation. Despite the high variability in surface and near-surface soil deposits, the presence of relatively large amounts of cohesionless coarser material underlain by relatively soft fine-grained material indicates that future consolidation settlement of the area will be rather general and will occur over the entire disposal area. An exception to this behavior will exist in the middle of the center compartment of the disposal area and the locations for the dikes across Pinto Pass are exceptions: these areas will undergo greater settlement more rapidly than is expected for other parts of the site.

22. The preliminary exploration indicates that it is potentially feasible to raise existing dikes and to construct new dikes in the north and south compartments of the disposal area with conventional designs and by conventional construction procedures, because a relatively stable base section exists along much of the proposed dike center line. However, the existance of numerous pockets and lenses of fine-grained material and the variation in relative density of the coarse-grained deposits indicate that a comprehensive sampling and soil testing program should be conducted prior to construction. This program would provide design data and ensure that designs selected for construction in the north and south compartments of the site will perform adequately, without failure during construction and long-term excessive differential settlement.

23. Across both ends and along the south edge of Pinto Pass, existing foundation conditions are such that normal construction methodology cannot be used to construct perimeter dikes according to Plan C.

Because of the proximity of abutting structures and improvements, especially at the west end of the pass, displacement techniques should not be attempted because of the resulting lateral soil displacement and mudflow. Once bearing failure and remolding of very soft sediments began, the displacement would probably occur to approximately el -40 before stabilizing. The volume of borrow material required would also make such construction exorbitantly expensive.

24. Detailed soil testing at WES provided data for appropriate foundation analyses and floating dike designs for initial Pinto Pass dike construction up to approximately el 8. Preliminary dike designs are discussed in Appendix A. However, during the construction phase, adequate instrumentation must be installed and monitored to ensure that design expectations are realized and to determine whether additional dike raising may be carried out in the 2-year increments estimated for planning purposes. Without these precautions, the dikes are likely to fail, resulting in extremely difficult and expensive repairs. For these reasons, and as conventional construction procedures may not be used, it may be desirable to construct a small section of the dike initially for use as a test section to verify methodology and refine construction procedures prior to contracting for construction of the entire job. More detail is given in Appendix A.

Site Operation and Maintenance Requirements

25. It should be noted that, in contrast to previous MDO and local sponsor operational methodology, the proposed Pinto Island Disposal Area would have to be maintained and monitored on a continuous bases. Good interior surface drainage and progressively deeper interior site drainage trenches must be maintained during the entire operating life of the site. Without such a continuing dewatering and reclamation program, potential maximum storage capacity would not be realized, and sufficient quantities of suitable material would not be available for carrying out the prescribed dike-raising activities after 1979.

26. It must be emphasized that the original estimates of future

dredging volume and available disposal capacity, while prepared with best available data, are only estimates. Thus, an integral part of any long-term plan for site operation and maintenance would be continuous monitoring and revision of the plan itself, to update projections as more accurate data become available and to adjust the plan to new situations and priorities as they arise.

Estimated Costs for Site Construction and Operation

27. Construction and operation of a carefully designed disposal area would, at first glance, seem more expensive than one built in an undesigned manner and treated thereafter with benign neglect. However, the result of neglect and inadequate design could well be costly delays and failures during both construction and operation and, more importantly, inadequate useful life of the site. Further, the site, once filled to capacity, would probably contain thick deposits of very wet dredged material with the consistency of warm axle grease, making it essentially useless for any productive purpose in either the immediate or the distant future. When the total cost of inadequate design and operation is computed, including the effect of poor public relations, inadequate capacity, and nonproductive land use, a more rational approach to confined dredged material disposal may have considerable merit. However, perhaps the best argument for rational design and operation is that proper long-range planning cannot be conducted when disposal sites are built and operated with only short-term goals.

28. Based on nationwide DMRP surveys, DMRP experimental data obtained at the North Blakeley Island Disposal Area, and existing labor and equipment costs in the Mobile area, the most economical way to increase disposal area storage volume is by perimeter dike construction, at a cost of $0.25 to $0.30 per cubic yard of storage volume created. The next most economical way to increase storage capacity is by a continuing program of providing good surface drainage and allowing the material to dewater and shrink naturally while it returns to soil form, at a cost of about $0.50 per cubic yard of storage volume created.

29. Dike construction across and along the south edge of Pinto Pass will be expensive, especially for Plan C, as special construction techniques must be employed. Estimated maximum costs of this construction are $600,000 for Plan C and $400,000 for Plan A. More detail is given in Appendix A. Other construction costs are computed on the basis of $0.27 per cubic yard to create storage volume by dike construction and $0.50 per cubic yard to create storage volume by dewatering. In addition, annual operation and maintenance (O&M) costs of $50,000 for administration and $30,000 for site maintenance have been included.

30. Estimated costs of operating the disposal area from 1977 through 2019 for both Plan A and Plan C are tabulated in Table 2 and are plotted in Figure 6. All costs are given in current (1977) dollars, and any special costs of site operation during actual disposal are assumed to be included in dredging costs. As may be seen from Table 2 and Figure 6, operation of the site through 2007 for Plan C will result in a total estimated expenditure of $11.58 million, or $0.42 per cubic yard of disposal volume. Plan A operation through 2019 will result in estimated expenditure of $16.49 million, or $0.41 per cubic yard of disposal volume. As may be noted from Figure 6, MDO funding requirements for both plans proceed at about the same rate, but Plan A requires longer term funding. The unit costs are comparable with those for other Corps disposal areas in the southeastern and southwestern United States and are considerably less than disposal storage costs in other parts of the country.

Possible Benefits and Other Considerations

31. When cooperative agreements among MDO, the local sponsor, and the property owners are used to provide disposal sites, a mutually beneficial arrangement must exist. There must be some inducement for property owners to make land available to MDO for extended periods, when land along and adjacent to navigable waterways is rapidly increasing in value. Further, property owners are not willing to see their land converted to disposal areas filled with material too wet and soft

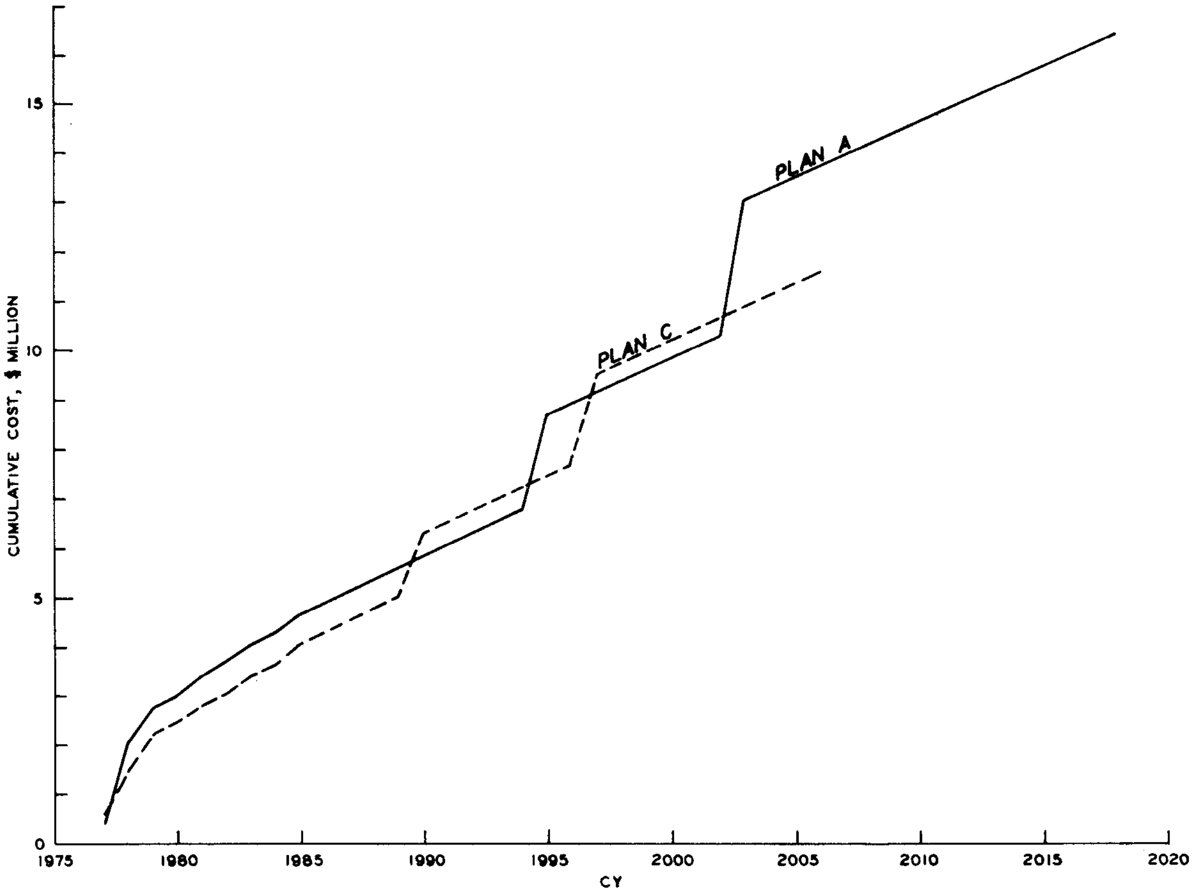


Figure 6. Estimated cost of operating proposed Pinto Island Disposal Area from 1977 to 2019 (1977 dollars)

to support any rational land use in the immediate or distant future. Conversely, MDO cannot reasonably be expected to expend effort in long-range planning and considerable public funds in disposal site construction, operation, and maintenance without positive assurance from the sponsor that the site will be available over the design time period.

32. Obtaining maximum potential storage capacity at Pinto Island will call for a continuous dredged material dewatering and reclamation program to increase disposal capacity and to create soil for use in incremental dike construction. The proposed procedure ensures that when the site is filled to capacity, it will be filled with dewatered dredged material, such that reasonably stable fast land of a form suitable for development and productive use will be created to el 50. Future availability of such land in close proximity to other industrial sites may be a long-term benefit of considerable value.

33. Initial construction of perimeter and interior dikes for either Plan A or Plan C will leave several hundred thousand cubic yards of high-quality coarse-grained borrow material available inside the north and south compartments of the site. Once this material is covered by disposal of fine-grained maintenance dredged material, it will be inaccessible. One alternative for local sponsor consideration might be to remove and sell this high-quality borrow before it is covered. The U. S. Army Engineer District, Philadelphia, has followed this practice for many years, awarding high-bid contracts for mining high-grade borrow in newly built disposal areas before they are used for disposal. Advantages to the sponsor and local economy include, respectively, generation of additional sponsor funds without taxation and local availability of relatively low-cost high-quality material. The main benefit to MDO would be additional dredged material storage capacity created by the mining operation.

34. Continuing MDO dewatering and reclamation activities at the site would also result in creation of some 27 to 40 million cu yd of dried fine-grained dredged material. This material would have potential productive use as landfill or topsoil or in engineering construction. Currently, economic considerations restrict its use in the Mobile area except in perimeter dike construction, but the economic picture may change in the future.

Potential Use of Other DMRP Technology

35. In addition to concepts for both initial and incremental dike construction, dredged material dewatering, and dried dredged material mining, other DMRP-developed technology could be put to effective use once decisions are made concerning the exact plan to be followed. These concepts include criteria for weir design and optimum placement; site operation during disposal to ensure that required effluent standards are met; and application of precise prediction and planning methodology to continuously refine and update the site master plan, as well as to allow rapid incorporation of any changes in future dredging quantities.

In addition, procedures are available for improving disposal area aesthetics and habitat between filling cycles, and for planning land-use development once areas are filled to design elevations.

Effects of Non-Corps Disposal

36. As noted previously, all assumed volumes of dredged material disposal were based only on continued MDO maintenance dredging of the Upper and Lower Tangents of the Mobile River. However, once MDO constructs a large disposal area on Pinto Island, it is likely that state and private interests will want to use the area to contain material dredged from other nearby locations in the harbor. While such practice in the past may not have greatly affected disposal area planning in any way except to reduce future capacity, more complex considerations are involved for the Pinto Island Disposal Area. Development and execution of a long-range disposal plan requires the ability to forecast, manage, and plan for future needs.

37. Based on past observation concerning non-Corps disposal operations in Mobile Harbor, it is noted that

- a. Dredging and disposal activities occur at irregular intervals and consist of both new-work and maintenance dredging.
- b. Accurate records of quantities dredged are not always available.
- c. Minimal attention is given to disposal area preparation and operation and to disposal area effluent quality.

38. Incorporating such semiplanned dredging and disposal operations in a long-range disposal plan is extremely difficult, as the net effect is to reduce design capacity not only by use of storage volume but also by disruption of ongoing dewatering and reclamation programs. Further, MDO should not be expected to invest considerable public funds in creation of disposal volume for any use that may not benefit the entire public sector.

39. One alternative is to prohibit disposal in the Pinto Island Disposal Area except by MDO. However, perhaps a better arrangement would be to design additional capacity into the desired life of the

site to consider such potential use and to expect any non-Corps users to pay an equitable fee for use of the site. This procedure has been followed by the U. S. Army Engineer District, Norfolk, at their Craney Island Disposal Area in Norfolk Harbor, Virginia. Based on previous cost calculations, an equitable user fee for the Pinto Island Disposal Area would be on the order of $0.41 to $0.42 per cubic yard of disposal volume. Such a user fee would provide for reimbursement of the actual costs for dewatering and reclamation of the material deposited by other interests. MDO should exercise control over time of dredging and operate the site during disposal by other interests. The former requirement allows use of the site by other interests to be considered, planned, managed, and coordinated with the MDO long-term site operation and maintenance plan, while the latter requirement is necessary because blame for improper site operation by other users and any resulting poor effluent quality would still likely be placed on MDO.

PART IV: SUMMARY AND RECOMMENDATIONS

Summary

40. The purpose of this study was to determine if the proposed Pinto Island disposal site could be effectively used as a long-term containment facility for maintenance dredging of the Upper and Lower Tangents of the Mobile River. Two plans were developed using the latest DMRP concepts and technology available. Plan A should provide adequate storage capacity until 2019, while Plan C will provide adequate storage capacity until 2007. Unit costs for both plans are similar. The result of either plan will be the creation of reasonably stable fast land to el 50.

41. Selection of final dike elevations lower than el 50 will result in shorter useful life. Results of final dike elevation-useful life calculations may be summarized in the following tabulation:

Plan	Final Dike Elevation	Useful Site Life, years
A	25	17
C	25	12
A	35	26
C	35	19
A	50	42
C	50	30

Useful-life data for other final dike elevations may be estimated by interpolation of these data and those from Figure 3. Useful-life data for other site configurations may be estimated by simple proportional relationships based on the acreage added or deleted by the revised site configuration. Useful life estimated from such proportional relationships will be somewhat low if acreage is deleted from the north and/or south compartments and somewhat high if acreage is deleted from the center compartment. Unit disposal volume costs should be reasonably comparable for any site configuration chosen. However, if more than about 25 percent of total acreage is deleted from Plan C, dredged material will have to be placed in lifts of more than 3 ft of sedimented thickness, hindering dewatering and reclamation activities.

42. If dredged material from non-Corps sources is to be placed in the disposal area, site capacity will be exceeded sooner than indicated by the given data. Further, the estimated storage volumes would be obtained only if a comprehensive long-term plan of site design and initial and future incremental construction, operation, and maintenance is undertaken, requiring a change in management philosophy for both MDO and the local sponsor.

Recommendations

43. Based on the information presented herein and the procedures and policies developed by the DMRP for optimum disposal site management, the following actions are recommended as being in the best interests of MDO:

a. Recommendation of a particular site configuration and/or final dike elevation for MDO adoption appears beyond the scope of the study. Data provided herein can provide the basis for such decisions by MDO personnel and the local sponsor, considering all aspects of future dredging and disposal for Mobile Harbor. From the viewpoint of specific disposal site operation and maintenance efficiency, DMRP-developed data tend to support selection of alternatives with the longest useful life.

b. The MDO should not undertake initial construction, operation, maintenance, and incremental future construction at the Pinto Island site without positive assurance from the local sponsor that the land will be available during the operating time period, as expenditure of substantial public funds would not otherwise appear justified.

c. Some agreement between MDO and the local sponsor should be reached either to prohibit use of the site for non-Corps disposal or to allow such disposal upon payment of an equitable user fee. In the latter instance, MDO should exercise control over time of dredging and site operation during disposal.

d. The data provided in this study should be used as a basis for decisions by MDO and the local sponsor concerning whether or not the Pinto Island Disposal Area should be developed and whether Plan A, Plan C, or other alternate plan will provide adequate long-term disposal capacity.

Once such decisions are made, detailed design, construction, operation, and maintenance procedures can be formulated to accomplish the desired results.

Table 1

Estimated Dredging Volume and Disposal Area Capacity for Proposed Pinto Island Disposal Area

	Estimated Dredging Volume, 10^6 cu yd		Available Disposal Area Volume, 10^6 cu yd									
			Plan C					Plan A				
Year	Annual	Cumulative	Dike Raising	Dewatering	Borrow	Cumulative	Remarks	Dike Raising	Dewatering	Borrow	Cumulative	Remarks
1977*	0.9 + 1.4	0	1.3	--	0.1	1.4	Center dike to el 8	1.3	--	0.1	1.4	Center dike to el 8
1978	--	0	2.4	--	0.2	4.2	North dike to el 25	5.3	--	0.2	6.9	North dike to el 25
1979	0.9	0.9	1.1 + 0.6	--	0.2	6.1	South dike to el 25	1.3 + 0.6	--	0.2	9.0	South dike to el 25
							Center dike to el 12					Center dike to el 12
1980**	1.4	1.3	--	0.3	--	6.4		--	0.3	--	9.3	
1981	0.9	2.2	0.6	0.3	0.1	7.4	Center dike to el 16	0.6	0.3	0.1	10.3	Center dike to el 16
1982	1.4	3.6	--	0.3	--	7.7		--	0.3	--	10.6	
1983	0.9	4.5	0.6	0.3	0.1	8.7	Center dike to el 20	0.6	0.3	0.1	11.6	Center dike to el 20
1984	--	4.5	--	0.3	--	9.0		--	0.3	--	11.9	
1985	0.9 + 1.4	6.8	0.7	0.3	0.1	10.1	Center dike to el 25	0.7	0.3	0.1	13.0	Center dike to el 25
1986	--	6.8	--	0.3	--	10.4		--	0.3	--	13.3	
1987	0.9 + 1.4	9.1	--	0.3	--	10.7		--	0.3	--	13.6	
1988	--	9.1	--	0.3	--	11.0		--	0.3	--	13.9	
1989	0.9	10.0	--	0.3	--	11.3		--	0.3	--	14.2	
1990	1.4	11.4	3.9	0.3	0.4	15.9	All dikes to el 35	--	0.3	--	14.5	
1991	0.9	12.3	--	0.3	--	16.2		--	0.3	--	14.8	
1992	1.4	13.7	--	0.3	--	16.5		--	0.3	--	15.1	
1993	0.9	14.6	--	0.3	--	16.8		--	0.3	--	15.4	
1994	--	14.6	--	0.3	--	17.1		--	0.3	--	15.7	
1995	0.9 + 1.4	16.9	--	0.3	--	17.4		6.3	0.3	0.4	22.7	All dikes to el 35
1996	--	16.9	5.9	0.3	0.8	24.4	All dikes to el 50	--	0.3	--	23.0	
1997	0.9 + 1.4	19.2	--	0.3	--	24.7		--	0.3	--	23.3	
1998	--	19.2	--	0.3	--	25.9		--	0.3	--	23.6	
1999	0.9	20.1	--	0.3	--	25.3		--	0.3	--	23.9	
2000	1.4	21.5	--	0.3	--	25.6		--	0.3	--	24.2	
2001	0.9	22.4	--	0.3	--	25.9		--	0.3	--	24.5	
2002	1.4	23.8	--	0.3	--	26.2		--	0.3	--	24.8	
2003	0.9	24.7	--	0.3	--	26.5		9.3	0.3	0.8	35.2	All dikes to el 50
2004	--	24.7	--	0.3	--	26.8		--	0.3	--	35.5	
2005	0.9 + 1.4	27.0	--	0.3	--	27.1		--	0.3	--	35.8	
2006	--	27.0	--	0.3	--	27.4		--	0.3	--	36.1	
2007	0.9 + 1.4	29.3	--	0.3	--	27.7	Site capacity exceeded	--	0.3	--	36.4	
2008	--	29.3						--	0.3	--	36.7	
2009	0.9	30.2						--	0.3	--	37.0	
2010	1.4	31.6						--	0.3	--	37.3	
2011	0.9	32.5						--	0.3	--	37.6	
2012	1.4	32.9						--	0.3	--	37.9	
2013	0.9	34.8						--	0.3	--	38.2	
2014	--	34.8						--	0.3	--	38.5	
2015	0.9 + 1.4	37.1						--	0.3	--	38.8	
2016	--	37.1						--	0.3	--	39.1	
2017	0.9	38.0						--	0.3	--	39.4	
2018	1.4	39.4						--	0.3	--	39.7	
2019	0.9	40.3						--	0.3	--	40.0	Site capacity exceeded

* Material dredged from the Lower Tangent placed in the South Blakeley Island Disposal Area. Material dredged from the Upper Tangent placed in the North Blakeley Island Disposal Area.

** 1,000,000 cu yd of material placed in the North Blakeley Island Disposal Area; 400,000 cu yd of material placed in the Pinto Island Disposal Area.

Table 2

Annual and Cumulative Costs in 1977 Dollars for Operation of

Proposed Pinto Island Disposal Area

	Annual and Cumulative Costs, Million Dollars							
	Plan C				Plan A			
Year	Construction	Dewatering	General O&M	Cumulative	Construction	Dewatering	General O&M	Cumulative
1977	0.60	--	--	0.60	0.40	--	--	0.40
1978	0.70	0.15	0.08	1.53	1.43	0.15	0.08	2.06
1979	0.46	0.15	0.08	2.22	0.51	0.15	0.08	2.80
1980	--	0.15	0.08	2.45	--	0.15	0.08	3.03
1981	0.16	0.15	0.08	2.84	0.16	0.15	0.08	3.42
1982	--	0.15	0.08	3.07	--	0.15	0.08	3.65
1983	0.16	0.15	0.08	3.46	0.16	0.15	0.08	4.04
1984	--	0.15	0.08	3.69	--	0.15	0.08	4.27
1985	0.19	0.15	0.08	4.11	0.19	0.15	0.08	4.69
1986	--	0.15	0.08	4.34	--	0.15	0.08	4.92
1987	--	0.15	0.08	4.57	--	0.15	0.08	5.15
1988	--	0.15	0.08	4.80	--	0.15	0.08	5.38
1989	--	0.15	0.08	5.03	--	0.15	0.08	5.61
1990	1.05	0.15	0.08	6.31	--	0.15	0.08	5.84
1991	--	0.15	0.08	6.54	--	0.15	0.08	6.07
1992	--	0.15	0.08	6.77	--	0.15	0.08	6.30
1993	--	0.15	0.08	7.00	--	0.15	0.08	6.53
1994	--	0.15	0.08	7.23	--	0.15	0.08	6.76
1995	--	0.15	0.08	7.46	1.70	0.15	0.08	8.69
1996	--	0.15	0.08	7.69	--	0.15	0.08	8.92
1997	1.59	0.15	0.08	9.51	--	0.15	0.08	9.15
1998	--	0.15	0.08	9.74	--	0.15	0.08	9.38
1999	--	0.15	0.08	9.97	--	0.15	0.08	9.61
2000	--	0.15	0.08	10.20	--	0.15	0.08	9.84
2001	--	0.15	0.08	10.43	--	0.15	0.08	10.07
2002	--	0.15	0.08	10.66	--	0.15	0.08	10.30
2003	--	0.15	0.08	10.89	2.51	0.15	0.08	13.04
2004	--	0.15	0.08	11.12	--	0.15	0.08	13.27
2005	--	0.15	0.08	11.35	--	0.15	0.08	13.50
2006	--	0.15	0.08	11.58	--	0.15	0.08	13.73
2007					--	0.15	0.08	13.96
2008					--	0.15	0.08	14.19
2009					--	0.15	0.08	14.42
2010					--	0.15	0.08	14.65
2011					--	0.15	0.08	14.88
2012					--	0.15	0.08	15.11
2013					--	0.15	0.08	15.34
2014					--	0.15	0.08	15.57
2015					--	0.15	0.08	15.80
2016					--	0.15	0.08	16.03
2017					--	0.15	0.08	16.26
2018					--	0.15	0.08	16.49

APPENDIX A: PRELIMINARY DESIGN FOR PINTO PASS DIKES

Introduction

1. As part of the Pinto Island Disposal Area feasibility study, solution of the major geotechnical engineering problem associated with disposal area feasibility was undertaken: dike construction across the east and west ends and along the south shore of Pinto Pass. Dike locations and preliminary construction sequence for the Pinto Pass dikes are described in the main text. The purpose of this appendix is to present general design considerations and constraints; review possible dike design alternatives; describe the selected preliminary design; and discuss proposed construction sequence, estimated construction costs, and expected behavior for the selected dike design.

General Design Considerations

2. The main consideration in dike construction across and along the south shore of Pinto Pass is the existing foundation profile. As a result of preliminary exploration by the Core Drill Section, MDO, and more detailed exploration, sampling, and testing carried out by the DMRP, it was established that extremely soft foundation conditions exist across both ends and along the south tidal line of the pass.

3. Across each end of the pass, surface elevations vary from approximately el +1 to el -1.5, and below the surface, very soft organic clays and silty clays with interbedded thin sand lenses exist down to approximately el -40. Field vane shear testing established that, for design purposes, the material could be divided into an upper 5-ft-thick stratum having an average cohesion c of 50 psf, underlain by another 5-ft stratum with cohesion $c = 100$ psf, underlain by approximately 30 ft of material with cohesion $c = 150$ psf. Below this last stratum, at el -40, medium dense to dense sand is found. Along the south tidal line of the pass, the profile is similar except that the average cohesion $c = 100$ psf in the upper 10 ft and the cohesive soils contain slightly more sand.

4. To design a dike for successful behavior both during and after construction, it is necessary to consider three potential failure modes: (a) foundation bearing failure during or immediately after construction; (b) dike slope failure during or immediately after construction and during disposal operations; and (c) dike failure from excessive total or differential consolidation settlement.

5. Based on containment area volume required to contain initial dredged material disposed in the center compartment of the Pinto Island Disposal Area, the dikes should be constructed up to approximately el 8 initially to provide sufficient freeboard. Final dike height, after rapid incremental raising, should be at el 25, and the dikes should provide the base section for future raising to el 35 or el 50.

6. For initial construction to el 8, assuming the dike to be constructed of coarse-grained cohesionless material available a short distance away in the south compartment of the proposed disposal area, the maximum (center-line) dike bearing pressure would be approximately 1000 psf. Ultimate bearing capacities for the soft strata underlying the center of the pass are approximately 300 psf for the $c = 50$ psf material, 600 psf for the $c = 100$ psf material, and 900 psf for the $c = 150$ psf material. Based on these data, the design problem is quickly reduced to one of providing adequate bearing capacity, as expected bearing pressure exceeds available foundation bearing capacity. Construction of a dike by normal procedures would result in bearing failure once the dike height passed approximately el 3. Unless adequate bearing capacity can be provided, analyses for slope stability and potential detrimental settlement would be meaningless. Further, the dike design must allow future incremental dike raising without bearing failure from the maximum expected bearing pressures (approximately 6000 psf for construction to el 50).

7. The normal engineering alternative in such instance is to preload the soft underlying material, allowing consolidation settlement to densify the material and increase its strength until design pressures may be carried without failure. Present foundation conditions will support conventional construction of a dike up to about el 3. Once

this dike was constructed, it could be raised incrementally in small stages to el 8 as the foundation consolidates. However, optimum long-term site operational considerations require that the dike be constructed to el 8 in the immediate future, and that it be raised as quickly as possible to el 25. With these general requirements and constraints, any proposed dike must

- a. Be constructed initially to el 8, preferably with coarse-grained borrow available nearby.
- b. Act as a containment dike to contain material from maintenance dredging and disposal operations.
- c. Act as a preload dike to consolidate underlying soft foundation soils to support future rapid incremental dike raising to el 25 without foundation bearing failure.
- d. Have an adequate factor of safety against dike slope failure and failure from excessive settlement.
- e. Provide an adequate base section for future long-term dike raising to a maximum of el 50.

Possible Dike Designs

8. Numerous alternate designs using these criteria were formulated and evaluated for potential use, including concepts of soft foundation excavation and replacement, use of sand berms, and dike construction with lightweight materials. However, of approximately 12 general design concepts reviewed, only 2 were found to offer potential technical success:

- a. Construction by end-dumping displacement, a procedure similar to that used for perimeter dikes at the North Blakeley Island Disposal Area.
- b. Construction of a "floating" dike, using filter cloth as internal tensile reinforcement to carry imposed excess bearing pressures.

After consideration, the floating design was selected as most promising, because displacement techniques would result in (a) potential for disruption or damage to abutting improvements at the west edge and along the south shore of the pass from resulting mud waves and lateral foundation displacement; (b) considerable additional cost compared with that of the floating dike design; and (c) less chance of effective construction control.

Proposed Dike Designs

9. Two different dike sections are proposed, one section to be built across the east and west ends of Pinto Pass and the other to be built along the south shore of the pass. The design section for the south shore assumes that the dike will be constructed according to Plan C of the proposed Pinto Island Disposal Area feasibility study, i.e. along the south tidal line. Should the dike be constructed as proposed in the Plan A configuration, across the existing ADDSCO parking lot, much less difficulty and cost would be involved. However, the worst-case design is presented.

10. The section proposed for initial dike construction across the east and west ends of Pinto Pass is shown in Figure A1. The dike is to

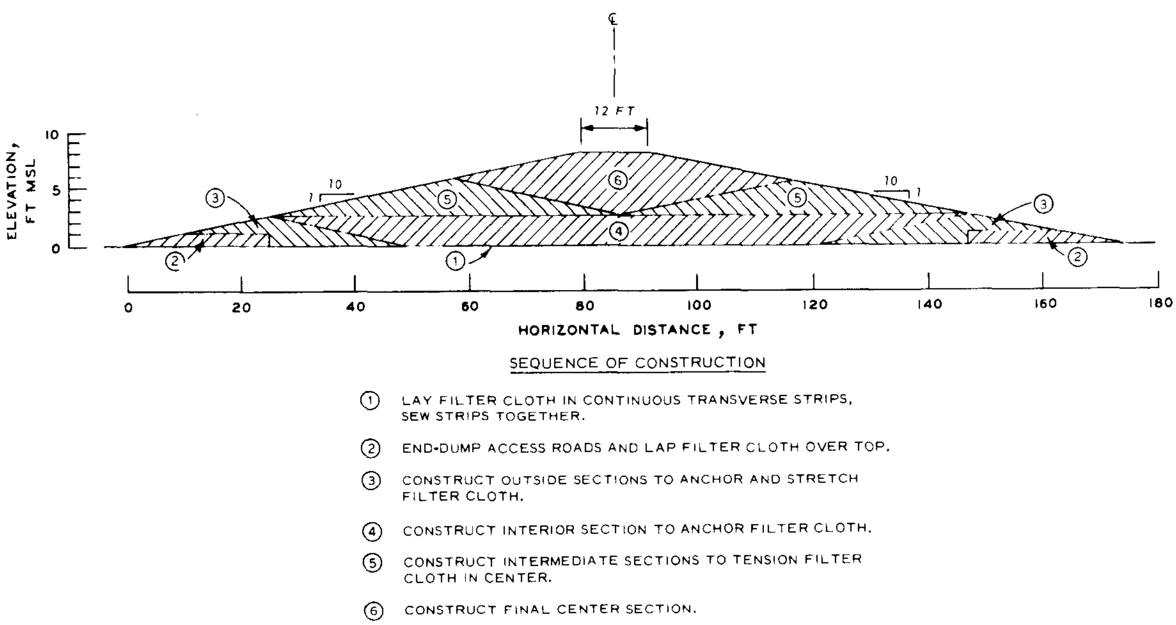


Figure A1. Cross section and construction sequence for proposed floating dike to el 8 across east and west ends of Pinto Pass

be constructed of coarse-grained material (sand) borrowed from the south compartment of the proposed disposal site and will have a 12-ft crest width at el 8 and 1V on 10H side slopes. Filter cloth reinforcement is provided at the base of the section. The relatively wide dike is chosen to

- a. Provide consolidation pressures over a wide area to effectively preload and increase the strength of underlying soft foundation sediment.
- b. Provide a stable base section for future dike raising.
- c. Allow filter cloth-sand interaction to cause internal stress redistribution from differential movement and arching, resulting in more nearly uniform pressures across the section.

11. The required construction sequence is also shown in Figure A1 and is extremely important in obtaining satisfactory performance of the dike. The required construction sequence will be subsequently described in detail but is summarized as follows:

- a. Filter cloth is laid on the surface in continuous transverse strips over a thin sand working table, with approximately 20-ft overlap or excess at each end, and adjacent transverse strips are slightly overlapped and sewn together.
- b. As filter cloth is placed, two outside access and anchorage strips are constructed up to about el 1.5, by placing material onto the filter cloth. These access strips are carried the entire length of the proposed section with the excess filter cloth at each end lapped and buried before the next operation is started.
- c. Two small outside dikes are then constructed to anchor the filter cloth, and resulting vertical settlement under these dikes stretches the filter cloth in the center section.
- d. The center section is then filled to anchor the filter cloth along the entire transverse length of the dike section.
- e. Intermediate dike sections are then constructed to cause settlement toward the outside of the dike, again tensioning the filter cloth in the center.
- f. The center section is constructed last, to design el 8.

12. As the filter cloth is deformed by the weight of overlying sand compressing the foundation, it develops tensile stresses that counteract frictional forces generated in the sand, preventing bearing failure deformations and reducing the net foundation contact pressure.

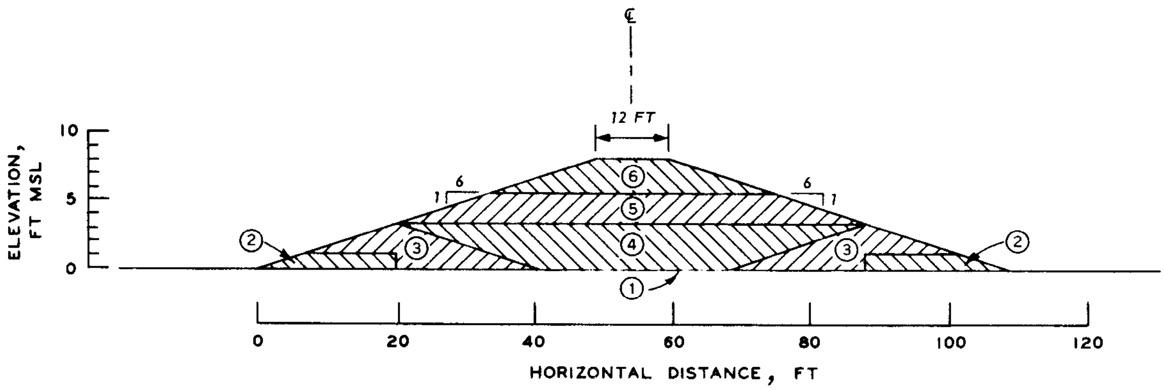
Also, relative internal displacements in the dike material cause internal arching, which serves to transmit vertical stresses in the center of the section toward the outside edges, where foundation contact pressure is less, thus resulting in a more nearly uniform distribution of bearing pressure across the entire dike section. Relative vertical deformations will also occur longitudinally along the dike center line, further tensioning the cloth. However, unless the prescribed construction sequence is followed carefully, the filter cloth will not be anchored and stretched properly, and thus cannot carry the necessary dike loadings without excessive dike deformation.

13. If filter cloth with an ultimate tensile strength of approximately 1000 lb per lineal foot in the transverse direction is used in construction, it is estimated that a factor of safety of between 2 and 2.5 will exist with respect to bearing failure. A polyester cloth may be suitable as this material is not subject to long-term creep under load. Many available filter cloths have an ultimate tensile strength at least 20 to 30 percent in excess of the required tensile strength. For safety purposes, it is suggested that a filter cloth be chosen having both a high tensile strength and a minimum of long-term creep under imposed loading. Cloths having a brittle mode of tensile failure should be avoided.

14. The proposed initial dike section along the south shore of Pinto Pass is shown in Figure A2. Because near-surface foundation soil strength was higher, a similar dike was recommended, but with 1V on 6H side slopes, thus reducing the amount of material required. A proper construction sequence is again required to correctly stretch and anchor the filter cloth tensile reinforcement, and is summarized in the figure.

Initial Dike Construction

15. Several considerations and operational problems exist which must be solved during dike construction across both ends of Pinto Pass, caused by need for placement of filter cloth and initial lifts of material on extremely soft soils in an intertidal zone. Existing soil



SEQUENCE OF CONSTRUCTION

① LAY FILTER CLOTH IN CONTINUOUS TRANSVERSE STRIPS, SEW STRIPS TOGETHER.

② END-DUMP ACCESS ROADS AND LAP FILTER CLOTH OVER TOP.

③ CONSTRUCT OUTSIDE SECTIONS TO ANCHOR AND STRETCH FILTER CLOTH.

④ CONSTRUCT FIRST CENTER SECTION TO ANCHOR FILTER CLOTH.

⑤ CONSTRUCT SECOND CENTER SECTION.

⑥ CONSTRUCT CENTER SECTION.

Figure A2. Cross section and construction sequence for proposed floating dike to el 8 along south shore of Pinto Pass

conditions are such that only about 3 ft of additional material may be placed conventionally before foundation bearing failure occurs. Specific problems to be solved include

a. Preparation of a working table and filter cloth placement (Item 1, Figures A1 and A2).

b. Construction of outside access and anchoring strips on the filter cloth (Item 2, Figures A1 and A2).

c. Construction of interior sections of the dike directly on the filter cloth (Items 3 and 4, Figures A1 and A2).

These problems will be addressed in subsequent sections. In all instances, it should be noted that considerable vertical settlements are expected (numerical values are given in a subsequent section) and desirable during dike construction. However, these settlements should result from elastic compression and consolidation of foundation soils, not from rotational foundation bearing failure and displacement. Also, tidal inundation during dike construction should not affect the strength of the free-draining dike per se during construction, except perhaps to temporarily reduce fill stresses by submergence and assist in material self-compaction. A more important consideration will be to schedule initial construction operations across both ends of the pass such that filter cloth placement occurs during lower tidal periods. Other operations, including fill placement, may be carried out during periods of normal tidal activity. Also, provision must be made for erosion protection of exposed outer dike faces during conduct of construction activities.

16. Operations described in following sections deal primarily with procedures required for construction by dragline borrow, truck hauling, and bulldozer spreading of dike material. However, hydraulic deposition of all material, if practical, would be considerably more cost-effective, and is discussed in a subsequent section.

Placement of working
table and filter cloth

17. Normal criteria for use of filter cloth in road construction on soft soils do not consider construction of a working table. Instead, the cloth is placed directly on the soft material and covered with sand, crushed shell, or other material providing adequate vehicle trafficability. This procedure has been used by contractors to build roads over soft ground in the Mobile area and by the Operations Division of the U. S. Army Engineer District, Savannah, to construct disposal site access roads and increase stability of disposal site perimeter dikes.

18. However, for the large-scale construction proposed and the probability that such obstacles as holes and channels exist along the proposed dike transverse width, construction of a working table appears justified. If the table is constructed properly, it should also minimize the amount of soft cohesive foundation material (mud) in contact with the cloth.

19. It is assumed that the working table will be constructed with coarse-grained material borrowed from the south compartment of the proposed disposal site. A working table up to 3 ft thick may be placed without causing foundation bearing failure. The only practical way to place the working table is by hydraulic deposition. As will be described subsequently, filter cloth will be precut to appropriate length (approximately 220 ft) and furnished in approximately 12- to 15-ft

widths. The initial working table segment, about 180 ft by 12 to 15 ft, will be placed from shore, using a sand slurry pump and manual direction of the discharge. The first strip of filter cloth (weighing approximately 175 to 200 lb) will be placed on the first working table segment by hand and unrolled. The filter cloth over working table will easily support the weight of the personnel moving the sand slurry discharge line to the edge of the filter cloth strip and placing the next part of the working table. The second strip of filter cloth is then placed and field-sewn to the first strip, while the third segment of the working table is placed. Concurrently, access roads are being constructed at each end of the cloth, by procedures to be described subsequently.

20. An alternative method of working table placement is to deposit the entire table at one time by hydraulic dredging prior to construction. This alternative may result in lower construction costs and facilitate construction, but considerations involving environmental protection and permit acquisition are beyond the scope of this report; thus the previous hand-work placement scheme was developed.

21. Unless the working table is placed to elevations above mean high water, filter cloth installation should be restricted to periods of lower tidal level, as the cloth will have an initial tendency to float, hindering placement, until air has been removed from the cloth voids. If the cloth is presoaked to remove this air, it will be too heavy for easy hand placement.

Initial access road construction

22. In conjunction with filter cloth placement, two access roads approximately 20 ft wide should be advanced along the outside edges of the proposed dike section, shown as Item 2 in Figures A1 and A2. The purpose of these roads is threefold:

- a. To anchor the outside edge of the filter cloth, preventing tidal flotation.
- b. To cause outside edge settlement, tensioning the interior filter cloth.
- c. To provide access for equipment and material needed to construct the remainder of the dike.

23. The access road will be constructed with a minimum 1.5-ft sand cover over the underlying foundation level filter cloth and 0.5-ft minimum cover over the second (lapped) filter cloth layer. Each layer of filter cloth may be expected to add an equivalent 5 CBR to roadway support capacity. Specific construction procedure is as follows:

a. Coarse-grained material is transported to the shoreline from the south compartment by small (bobtail, 5-cu-yd capacity) dump trucks or by tandem-axle dump trucks loaded to less than full capacity, and dumped adjacent to the first filter cloth strip.

b. A small, wide-track bulldozer then pushes, spreads, and track-compacts the material on top of the filter cloth, keeping 1-ft minimum cover on the bottom cloth layer at all times, and staying the width of one filter cloth strip behind the filter cloth placement operation.

c. After a 1-ft track-compacted layer is established, the extra 20 ft of filter cloth remaining at each end of the dike section is lapped over and laid on top of the access strip. The bulldozer then spreads and track-compacts a further 0.5 ft of coarse-grained material over this second layer. The lapped and covered layer gives the roadway additional strength, anchors the filter cloth, and provides tidal and wave action protection to the outside edges of the access strip.

d. As the access strips increase in length, dump trucks may now back out onto the completed parts of the strips to dump their loads closer to the bulldozer. Crushed shell or other wearing surface is placed last, to facilitate future vehicle traffic.

This operation may be conducted during normal tidal variation if care is taken to prevent rapid vehicle movement (and thus quick conditions) during high tidal levels. Temporary partial submergence of the free-draining material will facilitate material self-compaction and temporarily reduce foundation loadings.

24. If needed for construction efficiency, a third access strip could be placed down the proposed dike center line. However, decisions concerning the third access strip should be based on size and number of available construction equipment items, borrow production and haul capacities, and estimated operation cycle time. These data will not be available until contracting details are developed and prepared.

Initial interior
<u>section construction</u>

25. Once the access strips are in place to anchor the filter cloth, sections of coarse-grained material (Item 3 in Figures A1 and A2) can be placed on the filter cloth in the interior part of the dike section just inside the access strips. Construction sequence is similar to that followed in access strip construction. Material is brought out on the access strips and dumped, and then moved, spread, shaped, and track-compacted by small wide-track bulldozers. A minimum 1- to 1.5-ft material cover is kept over the filter cloth during this operation. Construction is advanced transverse to the access strips.

26. The last section to be placed directly on the filter cloth is the center section, Item 4 in Figures A1 and A2. Construction of this segment may be advanced from the shore by dumping, spreading, and track-compacting material with a wide-track bulldozer, again maintaining a minimum 1.5-ft cover over the filter cloth. Construction may also proceed simultaneously transverse to the intermediate sections (Item 3 in Figures A1 and A2), with material hauled and dumped along the access strips. Once a 1.5-ft semi-compacted cover on the filter cloth is in place, trucks may back onto the fill to dump closer to the bulldozer.

<u>Final construction sequence</u>

27. When all portions of the filter cloth have been covered, the remainder of the dike can be constructed. The initial part of the dike section (Items 1-4) will provide a stable working table for remaining construction, again using dump trucks to bring the material and bulldozers to spread and track-compact the material.

Construction of Entire Dike By Hydraulic Fill

28. Construction procedures have been presented for conventional hauled borrow construction of the proposed dikes. In this sequence, it was noted that hydraulic placement of the working table would facilitate construction operations. This concept may be extended to construction of the entire dike section with the following considerations:

a. Material must be deposited in the construction sequence described in Figures A1 and A2. This should be possible by proper control of the dredging operation. Operations can be conducted across the entire section length if desired.

b. Material selected for use as hydraulic fill should not contain a fine-grained fraction, as this may inhibit initial free-draining capability of the dike. Ponding should be minimized during construction.

c. Somewhat higher loadings may be placed on the filter cloth from saturated rather than moist weight of fill material.

d. A bulldozer may be required to provide final grading and shaping of the dike.

None of these problems are insolvable; in fact, carefully controlled hydraulic material placement offers a considerable potential cost savings over material placement by conventional means, as will be discussed subsequently.

29. The major deterrent to hydraulic construction may be such administrative details as approval of dredging. Adequate quantities of sand are available in the adjacent Mobile Harbor area. However, another alternative that should be considered is to mobilize a small dredge for placement in the south compartment of the proposed disposal area and remove the available coarse-grained material in this compartment for use in dike construction. By this procedure, permit requirements for open-water dredging may be avoided and MDO gains disposal area volume equal to the volume of borrow removed.

30. Problems encountered include dredge mobilization and sufficient water to conduct the operation. However, a railroad spur is located adjacent to the south compartment to aid in dredge mobilization, and the preliminary soils investigation noted numerous thin silt/clay lenses in the coarse-grained borrow that should trap and hold pumped-in water. A small Mudcat-type dredge could be obtained to pump clear water to the sand mining dredge continuously.

31. In summary, several potential advantages exist for total hydraulic construction, and this alternative should be seriously considered.

32. The proposed perimeter dike construction sequence involves

a number of construction operations that must be carefully coordinated to produce desired results. If time is available, the optimum procedure would be to contract for construction of the Pinto Pass dikes in two stages. The first contract would be for approximately 400 ft of dike construction across the west end of Pinto Pass. This initial section could be built as a test section to allow development of proper field construction procedures, determine expected production rates, etc. If the results of test section construction are favorable, a second contract for the remaining dikes may be let. If the results are unsuccessful, the other technically feasible but more expensive displacement alternative may be used to finish the test section and construct the remaining dikes.

33. The test section should probably be built by rental contract, providing MDO flexibility in adjusting necessary construction operations. Data developed during test section construction may be used to write specific and detailed plans and specifications for turnkey construction of the remaining dikes.

Suggested Weir Design

34. Preliminary design considerations for the center compartment of the proposed Pinto Island Disposal Area indicate that either two or three weirs should be placed in the dike at the east end and one weir at the west end of Pinto Pass. Because of the large settlements expected to occur along the dike center line, spillway-type weirs are recommended for initial use, rather than the drop inlet-buried outlet type normally used by MDO. Weir locations can be excavated after construction of the dike and entrance and exit channel slopes protected with riprap over filter cloth.

35. This type of construction will settle along with the dike and disposed material, preventing minimum weir flow line elevations from being above the dredged material surface. Once the perimeter dikes are raised and the foundation strengthened from preloading, drop inlet weirs may be placed. Spillway weir exit channels will facilitate later outlet pipe placement.

Incremental Dike Raising To El 25

36. As described in the main text and discussed previously in this appendix, it is necessary for the initial dike section to preload and consolidate existing soft foundation soils, increasing their strength so that the dikes can be incrementally constructed to el 25 as quickly as possible. The proposed dike raising sequence for the section across the east and west ends of Pinto Pass is shown in Figure A3. As mentioned in the main text, it is assumed that a movable header dredged material distribution system will be emplaced along the interior side of the dike with the deposited coarse-grained material adjacent to the dike forming part of the future incremental construction and providing a source of good borrow material for the raising. As shown in the

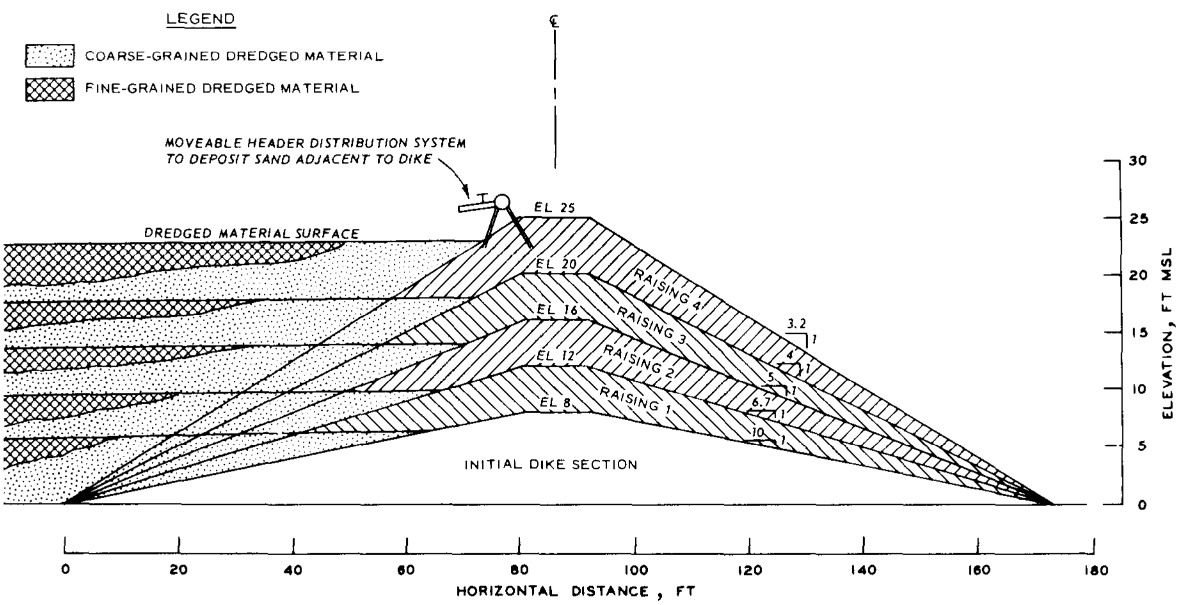


Figure A3. Incremental raising sequence for dike across east and west ends of Pinto Pass

figure, raising to el 25 is recommended in four increments, with the segments placed symmetrically on the initial dike and the final section having a 1V on 3.2H slope. This final section provides an adequate base for future dike raising, benched toward the inside of the disposal area, to el 35 or el 50. A similar incremental construction sequence is shown in Figure A4 for the dike section along the south shore of

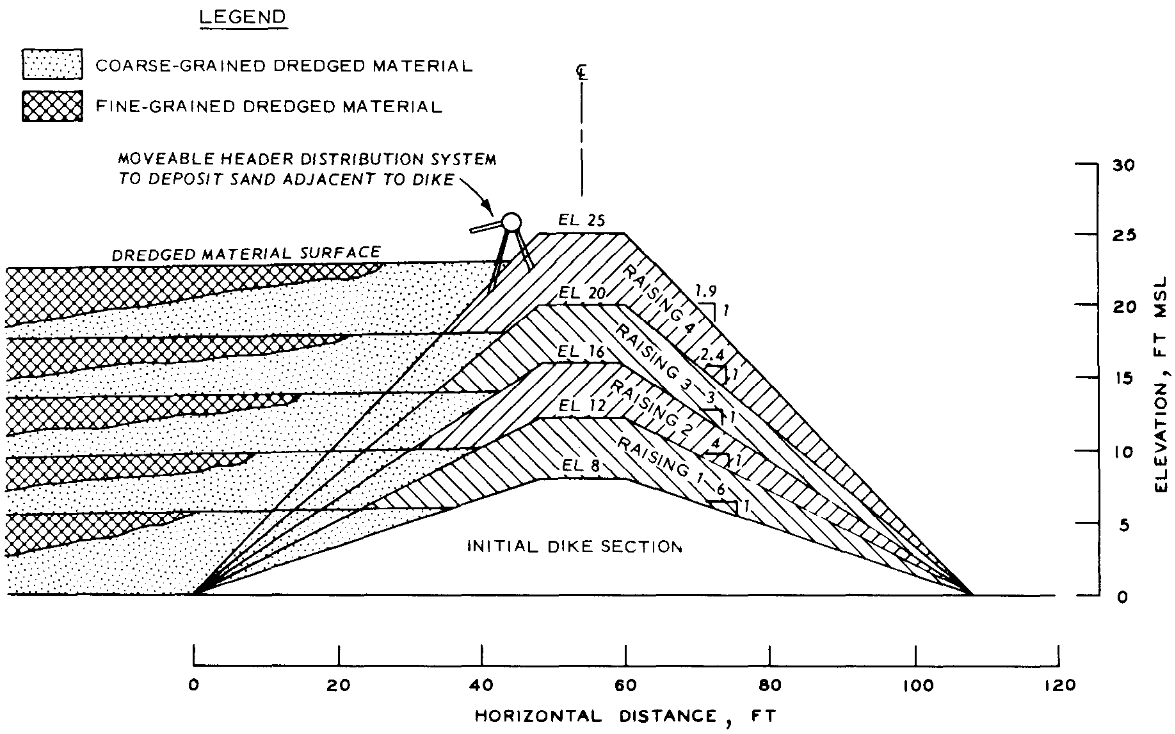


Figure A4. Incremental raising sequence for dike along south shore of Pinto Pass

the pass, resulting in final side slopes of 1V on 1.9H at el 25.

37. Although the movable header system recommended for use along the floating dike represents a new concept in MDO dredged material disposal, the concept has been used for many years in other types of high-water-content waste disposal. The system is frequently used in industry because of its cost-effectiveness and facilitation of dike raising. The primary purpose of the header system is to deposit any coarse-grained material evenly along the inside edge of the perimeter dike. While installation and operation of the header system will be an additional expense, it has several advantages:

a. Nearby coarse-grained borrow for incremental raising will be available only for the first raising to el 12, after which it will be covered with fine-grained dredged material.

b. As shown in Figure A3, coarse-grained material deposited in situ adjacent to the dike may be incorporated as part of the subsequent raised dikes, reducing dike raising costs. Coarse-grained material deposited outside the raised dike profile may be borrowed directly for use in dike raising without loading and transport from a central sand pile deposited by a single dredged pipe. Cost savings from reduced dike raising costs should pay for the installation and operation of the header system.

c. A large sand pile produced by a single dredge pipe could cause foundation bearing failure and displacement. If this failure occurred adjacent to a section of the floating dike, it might affect dike stability.

d. Excess coarse-grained material deposited along the inside dike perimeter (Figures A3 and A4) during interim operations will provide a more stable base section for inward-benched dike raising to el 35 or el 50 in the future.

38. It was assumed in the main text that preloading would develop sufficient subsurface bearing capacity to allow incremental dike raising in 2-year intervals. Preliminary laboratory testing and analysis have indicated that this assumption is potentially feasible. However, considerable variance usually exists between the calculated rate of pore pressure dissipation under consolidation stresses and the actual rate of dissipation observed in the field. Thus, final decisions on when incremental dike raising should be undertaken must be based, in large measure, on the magnitude of measured pore pressures in the foundation. These considerations, as well as others involving installation and monitoring of instrumentation, will be discussed in later sections.

Estimated Conventional Construction Costs

39. Based on previous experience in the Mobile area, it was estimated that coarse-grained material could be borrowed from the south compartment, transported to the job site, dumped, and spread for $2.50 per cubic yard. Cost of filter cloth was estimated at $1.00 per square yard, with labor costs for placement and sewing estimated at $0.50 per square yard.

40. Approximately 2800 lin ft of dike is needed to cross the east and west ends of Pinto Pass. The proposed section shown in Figure A1 requires approximately 41 cu yd of material and 24 sq yd of filter cloth per lineal foot of dike. Total initial construction cost for this section was thus estimated at approximately $400,000.

41. An additional 2800 lin ft of dike is required along the south

shore of Pinto Pass. Using the section shown in Figure A2 and the same unit prices, total cost of construction was estimated at approximately $185,000. When an additional $50,000 is included for acquisition and installation of required instrumentation, the estimated total cost of initial dike construction to el 8 is estimated at $635,000.

42. In computing comparative costs for the other technically feasible dike construction alternative, that of displacement, it was estimated that according to existing foundation soil strengths, approximately 1.5 ft of underlying soft material would be displaced for each foot of dike built above ground. Under these conditions, and using the same unit price ($2.50 per cubic yard) for materials, estimated initial construction cost for the Pinto Pass dikes was approximately $1,040,000, or $400,000 more than required for the floating design. If only 1 ft of displacement is required to obtain 1 ft above ground (probably not a conservative estimate), then the estimated cost drops to approximately $830,000, still $200,000 more than the floating design.

Estimated Hydraulic Construction Costs

43. In estimating costs of material placement by hydraulic fill, it was noted that dredging costs for recent similar-scale jobs in the Mobile area have averaged $0.75 to $1.00 per cubic yard. To consider the extra costs associated with dredge mobilization to the south compartment, water pumping required, and careful pipe placement and movement needed to follow prescribed construction sequencing, a unit cost of $1.25 per cubic yard was estimated for hydraulic placement. Filter cloth-related costs remain the same, but reduced material costs result in a total estimated cost of $250,000 for the 2800 lin ft of dike across both ends of the pass and $128,000 for the 2800 lin ft of dike along the south shore of the pass. Assuming that the $50,000 allocated for instrumentation remains constant, total cost for hydraulic construction of the floating dike is $428,000, or only 67 percent of the $635,000 estimated for conventional construction.

44. Costs for displacement construction by hydraulic material

placement will be proportionally greater than for floating construction because of the greater material quantities needed, as described in the previous section.

Expected Foundation Consolidation

45. As mentioned previously, the Pinto Pass dikes are to act as preload structures as well as containment structures. In their preload function they served to consolidate underlying soft sediments, developing increased strength necessary to carry higher foundation loadings resulting from future incremental dike raising. In soft soils, consolidation settlement from initial load increments is usually of large magnitude and decreases with future incremental loadings of similar magnitude as the soil compresses and becomes stronger.

46. Such behavior was found to occur for Pinto Pass dike construction. Maximum vertical consolidation is expected to occur along the center line of the dike across the east and west ends of Pinto Pass. Settlements are expected to be smaller along the outer parts of these dikes and for the dikes along the south shore of the pass. Average settlements should be approximately one half the maximum values. Maximum anticipated settlements were computed assuming normally consolidated soil, a 40-ft sediment thickness, an average initial void ratio of 2.7, and coefficient of compressibility $C_c = 0.9$. Based on these probably conservative values, expected maximum settlement is as follows:

Dike Construction Increment	Expected Maximum Vertical Settlement: Incremental, ft	Expected Maximum Vertical Settlement: Total, ft
Initial Construction to el 8	2.9	2.9
Raised to el 12	1.2	4.1
Raised to el 16	0.9	5.0
Raised to el 20	0.7	5.7
Raised to el 25	0.8	6.5
Raised to el 35	0.9	7.2
Raised to el 50	0.7	7.9

47. As noted, settlements are considerable, but no more than usually expected for such soft foundation soils. It is probable that some 30 percent or more of the settlement will occur during construction, with the majority of the remaining settlement occurring soon after construction is terminated.

48. Estimation of field time-settlement behavior is subject to many assumptions; thus the best estimates of settlement rate and expected total settlement should be determined using field data collected during actual construction. It should also be noted that the expected settlement profile, with maximum settlements in the center, will assist in desired tensioning of the filter cloth, with resultant arching and load redistribution toward the outside of the dike section reducing the maximum bearing pressure. Thus, for several reasons, the error in magnitude of estimated settlements is believed to be on the safe side.

Required Instrumentation

49. To ensure that the proposed construction sequences of Figures A1 and A2 are providing the desired results and that actual dike and foundation behavior agrees with predicted behavior, as well as to provide data on the appropriate time for future incremental dike raising, proper instrumentation must be installed and monitored, both during and after construction of the Pinto Pass dikes. Necessary information includes the relative horizontal and vertical movement of the dike section, especially during construction, and the excess pore pressures generated in the foundation, both during and after construction. Most complex and sophisticated instrumentation is suitable only for demonstration, and usually does not work properly under field conditions. Installed instrumentation should be limited to only those types that are simple and have a proven history of effective performance. Thus, it is recommended that at every other 100-ft station along the dike center line for the entire length of dike construction the following simple instrumentation be installed:

a. Casagrande-type porous stone piezometers should be placed at the outside edges and center of the dike at depths of 5, 10, 20, and 40 ft below the surface, and should be placed to depths of 5 and 10 ft at the interior quarter points.

b. Horizontal and vertical control points should be placed 20 ft apart transversely across the dike surface on each side of the center line, and settlement plates should be installed at foundation level at the center and outside edges of the dike.

If test section construction is contemplated, more instrumentation should be installed, perhaps on 50-ft centers over the 400-ft length.

50. Temporary reference points may be necessary during construction; the permanent reference points can be installed once construction is complete. Once construction is initiated, piezometers must be installed as quickly as possible. All piezometers should be read daily and results plotted within 24 hours after collection so that any potentially dangerous pore pressure trends during construction may be quickly recognized and corrective action taken. Horizontal and vertical control data should be collected daily and reduced and displayed within 24 hours after data collection to indicate any potentially dangerous trends of excessive settlement or lateral movement during the construction phase. Once construction is complete, piezometer levels and vertical control data should be obtained periodically, at monthly or bimonthly intervals, to determine rates of settlement and pore pressure dissipation, and allow estimation of time for the next incremental dike raising. It should be noted that, unless adequate instrumentation is installed, monitored, and results displayed immediately, and these results evaluated by qualified geotechnical engineering personnel, no assurance will be available that field conditions are in reasonable agreement with those assumed for design purposes.

Erosion Protection

51. It should be noted that the east slope of the dike across the east edge of Pinto Pass will be subject to some wave action. However, the dike is in a relatively protected location, and the observed wave

patterns appear to be in a north-south direction. Little observed erosion or wave damage has occurred to shoreline or existing dikes adjacent to the proposed construction site. The 1V on 10H outside slope with 100-ft wave runup of the initial dike is similar to that found on natural beaches, and if vegetation is quickly established on this outer dike slope, it is not anticipated that additional erosion protection will be required. To facilitate vegetation establishment, it may be desirable to cover the dike slope with approximately 6 in. of dewatered fine-grained dredged material borrowed from the North Blakeley Island Disposal Area, which may be more conducive to vegetation establishment than the coarse-grained dike construction material. If necessary, outside slopes may be protected with riprap-covered filter cloth.

Conclusions

52. Considering the multiple purposes required for the Pinto Pass dikes, i.e., to act as initial containment structures at el 8, as preload structures to facilitate rapid incremental construction to el 25, and as substructures for long-term dike raising to el 50; and considering available material, alternative methods of dike construction, and relative costs, the proposed floating dike sections appear to be the least expensive alternative, provide the best substructure for future incremental dike raising, and offer the highest probability of successful performance.

53. Based on material presented and discussed herein, the following concepts should be considered in implementation of the suggested design:

- a. If available time permits, constructing the short dike segment across the west end of Pinto Pass as a test section has the technical advantage of allowing methodology and construction procedure verification and adjustment, and the practical advantage of providing data to prepare appropriate plans and specifications for turnkey construction of the remaining dikes.
- b. Construction of the dikes by hydraulic material placement would result in an estimated 33 percent reduction in total costs; therefore, this alternative should be seriously considered. If hydraulic methods are operationally impractical, conventional haul, dump, and spread construction methods may be used.

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Haliburton, T Allan
Feasibility of Pinto Island as a long-term dredged material disposal site / by T. Allan Haliburton, Patrick A. Douglas, Jack Fowler. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. available from National Technical Information Service, 1977.
29, [2], 21 p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; D-77-3)
Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under DMRP Work Unit No. 5A16.

1. Dredged areas. 2. Dredged material disposal. 3. Feasibility studies. 4. Pinto Island. 5. Waste disposal sites. I. Douglas, Patrick Avant, joint author. II. Fowler, Jack, joint author. III. United States. Army. Corps of Engineers. IV. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; D-77-3.
TA7.W34m no.D-77-3